US Army Corps
of Engineers
Construction Engineering
Research Laboratories

USACERL ADP Report 95/20
August 1995

Department of Defense (DOD) Renewables and Energy Efficiency Planning (REEP) Program Manual

by
Robert J. Nemeth
Donald Fournier
Lee Debaillie
Lee Edgar
Peter Stroot
Robert Beasley
Daiva Edgar
Leigh McMillen
Marty Marren

The Renewables and Energy Efficiency Planning (REEP) program was developed at the U.S. Army Construction Engineering Research Laboratories (USACERL). This program allows for the analysis of 78 energy and water conservation opportunities at 239 major DOD installations. REEP uses a series of algorithms in conjunction with installation specific data to estimate the energy and water conservation potential for entire installations. The program provides the energy, financial, pollution, and social benefits of conservation initiatives. The open architecture of the program allows for simple modification of energy and water conservation variables, and installation database values to allow for individualized analysis. The program is essentially a high-level screening tool that can be used to help identify and focus preliminary conservation studies.

The REEP program requires an IBM PC or compatible with a 80386 or 80486 microprocessor. It also requires approximately 4 megabytes of disk space and at least 8 megabytes of RAM. The system was developed for a Windows environment and requires Microsoft Windows™ 3.1 or higher to run properly.

USER EVALUATION OF REPORT

REFERENCE: USACERL ADP Report 95/20, *Department of Defense (DOD) Renewables and Energy Efficiency Planning (REEP) Program Manual*

Please take a few minutes to answer the questions below, tear out this sheet, and return it to USACERL. As user of this report, your customer comments will provide USACERL with information essential for improving future reports.

1. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which report will be used.)

2. How, specifically, is the report being used? (Information source, design data or procedure, management procedure, source of ideas, etc.)

3. Has the information in this report led to any quantitative savings as far as manhours/contract dollars saved, operating costs avoided, efficiencies achieved, etc.? If so, please elaborate.

4. What is your evaluation of this report in the following areas?

   a. Presentation: ________

   b. Completeness: ________

   c. Easy to Understand: ________

   d. Easy to Implement: ________

   e. Adequate Reference Material: ________

   f. Relates to Area of Interest: ________

   g. Did the report meet your expectations? ________

   h. Does the report raise unanswered questions? ________

i. General Comments. (Indicate what you think should be changed to make this report and future reports of this type more responsive to your needs, more usable, improve readability, etc.)

5. If you would like to be contacted by the personnel who prepared this report to raise specific questions or discuss the topic, please fill in the following information.

Name: ______________________

Telephone Number: ______________________

Organization Address: ______________________

6. Please mail the completed form to:

Department of the Army
CONSTRUCTION ENGINEERING RESEARCH LABORATORIES
ATTN: CECER-TR-I
P.O. Box 9005
Champaign, IL 61826-9005

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave Blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	August 1995	Final

4. TITLE AND SUBTITLE

Department of Defense (DOD) Renewables and Energy Efficiency Planning (REEP) Program Manual

5. FUNDING NUMBERS

MIPRs E87920506, E8793R038, DSAM20076, W24, and E87940378.

6. AUTHOR(S)

Robert J. Nemeth, Donald Fournier, Lee Debaillie, Lee Edgar, Peter Stroot, Robert Beasley, Daiva Edgar, Leigh McMillen, and Marty Marren

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Construction Engineering Research Laboratories (USACERL)
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER

ADP Report 95/20

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Center for Public Works (USACPW)
ATTN: DAIM-FDF-U
7701 Telegraph Road
Alexandria, VA 22310-3862

Office of the Deputy Undersecretary of Defense
ATTN: ODUSD/ES/C&I
400 Army Navy Drive, Suite 206
Arlington, VA 22002-2884

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The Renewables and Energy Efficiency Planning (REEP) program was developed at the U.S. Army Construction Engineering Research Laboratories (USACERL). This program allows for the analysis of 78 energy and water conservation opportunities at 239 major DOD installations. REEP uses a series of algorithms in conjunction with installation specific data to estimate the energy and water conservation potential for entire installations. The program provides the energy, financial, pollution, and social benefits of conservation initiatives. The open architecture of the program allows for simple modification of energy and water conservation variables, and installation database values to allow for individualized analysis. The program is essentially a high-level screening tool that can be used to help identify and focus preliminary conservation studies.

The REEP program requires an IBM PC or compatible with a 80386 or 80486 microprocessor. It also requires approximately 4 megabytes of disk space and at least 8 megabytes of RAM. The system was developed for a Windows environment and requires Microsoft Windows 3.1™ or higher to run properly.

14. SUBJECT TERMS

computer programs
energy conservation
Renewables and Energy Efficiency Planning (REEP)

15. NUMBER OF PAGES

526

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

Foreword

This study was conducted for the U.S. Army Center for Public Works (USACPW) and the Office of the Deputy Undersecretary of Defense (ODUSD) under Military Interdepartmental Purchase Requests (MIPRs) No. E87920506, "Basic Energy Analyzing Algorithms," E8793R038, "Renewables and Energy Efficiency Program," DSAM20076, "Energy Efficiency Evaluation Model for DOD Installations," W24 "Expansion of Renewables and Energy Efficiency Planning Model," and E87940378, "Finalize DOD REEP Model." The technical monitors were Satish Sharma, DAIM-FDF-U, and Millard Carr, ODUSD/ES/C&I.

The work was performed by the Engineering Division (FL-E) of the Facilities Technology Laboratory (FL), U.S. Army Construction Engineering Research Laboratories (USACERL). Dr. Robert Beasley, University of Illinois at Urbana-Champaign (UIUC) has performed all programming and done an outstanding job. Peter Stroot, Leigh McMillen, and Marty Marren (UIUC students) have sorted, deciphered, and manipulated an incredible amount of data for the installation and utility databases. Other USACERL contributors are Lee Edgar, Daiva Edgar, Lee DeBaille, and Gerald Cler. All have spent innumerable hours developing energy conservation opportunity algorithms and supporting documentation. The assistance of Lane Ingram, Jon Hanson, Jerry Dewitt, Richard Rundus, Doug Howenstein, and Charles Marsh is also appreciated. Alvin Smith is Acting Chief, CECER-FL, Donald F. Fournier is Acting Operations Chief, CECER-FL, and Larry M. Windingland is Acting Chief, CECER-FL-E. The USACERL technical editor was Linda L. Wheatley, Technical Resources Center.

COL James T. Scott is Commander and Acting Director of USACERL, and Dr. Michael J. O'Connor is Technical Director.

Contents

List of Tables and Figures

Tables

Figures

1 Introduction

Background

Defense Management Review Decision 907 directs a formal program to reduce facilities energy use and cost. Defense Energy Program Policy Memorandum (DEPPM) 91-2 implements this decision and requires the Department of Defense (DOD) to reduce facilities energy consumption and costs by 20 percent from 1985 to 2000, while using a defined set of strategies. Executive Order 12902 of 8 March 1994 (59 FR 11463-11471) increased the energy saving requirement for agencies to 30 percent by the year 2005.

DOD is the proprietor of millions of square feet of facilities across a broad spectrum of installations in different climatic regions. In the Continental United States (CONUS) alone, the U.S. Army owns over 748 million sq ft of facilities. Approximately 39 percent of this square footage is housing and barracks, and the remaining square footage consists of training, maintenance, storage, commercial, medical, administrative, and miscellaneous types of facilities. In 1991, DOD paid more than $870 million in utility costs at these facilities. Of this amount, almost $445 million was electrical costs (U.S. Army Engineering and Housing Support Center [USAEHSC] 1992, commonly known as the Red Book). The statistics for the U.S. Air Force and U.S. Navy are similar.

For DOD to appropriate adequate funding to meet the energy reduction goals, the agency needs the means to assess the energy and economic savings potential of various energy conservation opportunities (ECOs) and budget sufficient economic resources to implement these measures. To acquire these means, the Chief of Engineers tasked the Concepts Analysis Agency (CAA) to develop and apply an analytical methodology for evaluating the economic potential for investment in energy efficiency and renewable energy in Army facilities. These complex analyses require consideration of such factors as energy use, system costs, persistence of energy saving opportunities, energy policy, funding alternatives, budget constraints, the facility mix, and environmental considerations. The CAA macro resource allocation model required the logical incorporation of these factors in the energy investment decisionmaking process. The CAA tasked the U.S. Army Construction Engineering Research Laboratories (USACERL) to develop the basic energy, financial, and pollution analyzing algorithms

and supporting data to be used in CAA's resource allocation model. Working in conjunction with Office of the Deputy Undersecretary of Defense/Environmental Security/Conservation & Installations (ODUSD/ES/C&I), USACERL has developed REEP into standalone energy-management software.

This document summarizes USACERL's efforts towards developing the Renewables and Energy Efficiency Planning (REEP) model, including data acquisition and ECO development and analysis. Also included are individual ECO descriptions, assumptions, and summaries. The REEP model contains the rules and supporting data for analyzing the economic potential for investment in energy efficiency and renewable energy technologies at 239 DOD installations.

Objectives

Motivation for DOD to address energy conservation emanated from the recognition that significant dollar savings could be achieved through the improved operations, maintenance, and energy savings retrofits to existing facilities. However, a method of identifying potential energy saving candidates had to be developed before a strategy for investment in energy conservation retrofits could be implemented. The goal of REEP is to identify economically viable energy conservation retrofits to DOD facilities considering building construction, use, utility rates, and climate. REEP identifies promising ECOs and eliminates those with long payback periods.

Approach

Assessing energy savings potential by conducting very detailed studies is expensive, requires large amounts of specific information about energy conservation, and applies to only very particular situations. Generalized studies take less ECO information and assess their potential across a much larger population of buildings and infrastructure. The REEP program uses a generalized approach for studying the potential of various ECOs across many DOD installations. While this approach is not as accurate as the detailed approach, applying a detailed approach across all DOD installations is virtually impossible because of the quantity, quality, and breadth of information required. The generalized approach allows rapid analysis of numerous ECOs using minimum data from each installation. This approach also provides estimates at a level of detail suitable for planning purposes. Quick identification of ECOs allows efforts to focus on detailed engineering studies where they will do the most good. Assessing conservation potential across such a large, distributed, and diverse building set is not simple. Relying on computer simulations was deemed the only reasonable approach to the

problem. The REEP model allows DOD to approach energy conservation from a macro-perspective before delving into details.

Mode of Technology Transfer

REEP software and documentation may be obtained directly from USACERL, be downloaded electronically from a computer at USACERL, or be obtained on CD-ROM on the Construction Criteria Database (CCB), which is distributed by the National Institute of Building Sciences (NIBS). The software and documentation packet from USACERL includes two 3.5 in. high-density disks and a users guide. The software that can be downloaded electronically from USACERL and the CCB CD-ROM includes the REEP program and electronic manual files. Instructions on downloading the REEP program electronically are at the end of this section.

In addition to the program and documentation, and to enhance technology transfer, significant efforts have been devoted towards publishing papers, writing articles, and disseminating information on the REEP program. A briefing on the program has been given at Army and Air Force Energy Managers meetings, papers on REEP have been presented at two Association of Energy Engineers conferences, and a briefing on it has been given at the Corps of Engineers National Energy Team meeting. Articles on REEP have been published in *American Public Works Association Reporter*, *Energy User News*, *Federal Facilities Environmental Journal*, *Military Engineer*, *Federal Energy Management Program Focus Newsletter*, and the *U.S. Army Public Works Digest*.

To obtain REEP from USACERL, please contact the FL-E Division at 1-800-872-2375. To obtain REEP on the CCB CD-ROM, contact NIBS at 202-289-7800. To download the REEP program from USACERL, follow these instructions:

1. Create two subdirectories on your local hard drive labeled 'disk1' and 'disk2'.
2. Connect to the FTP site by using either the host name (emma.cecer.army.mil) or the IP address (129.229.66.60).
3. At the username prompt type 'anonymous' in lowercase.
4. Enter your e-mail address as the password.
5. Switch to the REEP subdirectory (of the FTP site).
6. Use binary mode when downloading.
7. Download 'disk1.zip' to the disk1 subdirectory and 'disk2.zip' to disk2.
8. Log out of the FTP site.
9. Unzip the files using PKUNZIP.

10. While in Windows, run 'setup.exe' from the disk1 subdirectory. This step can be accomplished in the Program Manager by using the Run command from the Files menu or by double clicking on 'setup.exe' in the File Manager.
11. After it prompts you, the program will create a directory on the hard drive and install the program to this new directory.
12. The disk1 and disk2 subdirectories may now be deleted or copied to two 1.44 Mb floppies. If you wish to transfer the subdirectories to floppies, do not copy the '.zip' files.

2 Program Overview

General

The REEP program projects estimated DOD-wide energy savings that are considered during budget development and program planning. The program uses a series of algorithms in conjunction with installation specific data to make estimates of the energy conservation potential for entire installations, providing the energy, financial, pollution, and social benefits of conservation initiatives. The program models 78 energy and water conservation opportunities (ECOs and WCOs) and has eight basic ECO/WCO categories: electrical, lighting, building envelope, HVAC (heating, ventilating, and air-conditioning), water, utilities, renewables, and miscellaneous.

The REEP program was developed using Microsoft FoxPro Version 2.5 for Windows™. FoxPro is a Relational Database Management System (RDBMS) with a built-in programming language that allows development of custom applications. The program requires an IBM PC or compatible with a 80386 or 80486 microprocessor. It also requires approximately 4 megabytes of disk space and at least 8 megabytes of RAM. The system was developed for a Windows environment and requires Microsoft Windows 3.1 or higher to run properly.

Installations in REEP

Table 1 provides a listing of the DOD installations included in REEP.

Table 1. DOD installations included in REEP.

	Army	Air Force	Navy
1	Aberdeen PG	AF Academy	Adak
2	Anniston DPT	Altus AFB	Yuma
3	Badger AAP	Andrews AFB	Camp Pendleton
4	Corpus Christi DPT	Arnold AFB	Lemoore
5	Detroit Ars Tank Pl	Barksdale AFB	Port Hueneme/Pt. Mugu

	Army	Air Force	Navy
6	Detroit Arsenal	Beale AFB	China Lake
7	Dugway PG	Bolling AFB	Barstow
8	Ft Monmouth	Brooks AFB	Twentynine Palms
9	Hawthorne AAP	Canon AFB	New London
10	Holston AAP	Charleston AFB	Jacksonville
11	Indiana AAP	Columbus AFB	Orlando
12	Iowa AAP	Davis-Monthan AFB	Pensacola
13	Jefferson PG	Dover AFB	Key West
14	Kansas AAP	Dyess AFB	Kings Bay
15	Lake City AAP	Edwards AFB	Albany
16	Letterkenny Army DPT	Eglin AFB	Pearl Harbor
17	Lexington Blue Grass AD	Ellsworth AFB	Great Lakes
18	Lima Tank Plant	Fairchild AFB	Indianapolis
19	Lone Star AAP	Falcon AFB	Crane NWSC
20	Longhorn AAP	Goodfellow AFB	Louisville
21	Louisianna AAP	Grand Forks AFB	Los Angeles Area
22	McAlester AAP	Griffiss AFB	New Orleans
23	Milan AAP	Gunter AFB	Brunswick
24	Mississippi AAP	Hanscom Field	Annapolis
25	Natick Dev Cen	Hill AFB	Indian Head
26	Newport AAP	Holloman AFB	Patuxent River
27	Picatinny Arsenal	Hurlburt Field	Meridian NAS
28	Pine Bluff Arsenal	K. I. Sawyer AFB	Gulfport
29	Pueblo DPT	Keesler AFB	Fallon
30	Radford AAP	Kelly AFB	Trenton
31	Ravenna AAP	Kirtland AFB	Lakehurst
32	Red River DPT	Lackland AFB	Colts Neck
33	Redstone Arsenal	Langley AFB	Bethpage
34	Rock Island Arsenal	Laughlin AFB	New York City
35	Sacramento Army DPT	Little Rock AFB	Norfolk
36	Savanna Depot Activity	Los Angeles AFS	Camp Lejeune
37	Scranton AAP	Luke AFB	Cherry Point
38	Seneca Army Depot	Malmstrom AFB	Mechanicsburg

	Army	Air Force	Navy
39	Sierra Army Depot	March AFB	Warminster
40	Sunflower AAP	Maxwell AFB	Philadelphia
41	Tobyhanna AD	McChord AFB	Newport
42	Tooele DPT	McClellan AFB	Miramar
43	Twin Cities AAP	McConnell AFB	San Diego
44	Umatilla Army DPT	McGuire AFB	Mare Island
45	Vintage Hill Farms Station	Minot AFB	Sunnyvale
46	Volunteer AAP	Moody AFB	San Francisco
47	Watervliet Arsenal	Mountain Home	Moffett Field
48	White Sands MR	Nellis AFB	Oakland
49	Yuma PG	Newark AFS	Alameda NARF
50	Ft A. P. Hill	Offutt AFB	Oakland Hospital
51	Ft Bragg	Onizuka AFS	Beaufort/Parris Island
52	Ft Buchanan	Patrick AFB	Charleston
53	Ft Campbell	Peterson AFB	Memphis
54	Ft Carson	Plattsburgh AFB	Dallas
55	Ft Devens	Pope AFB	McGregor
56	Ft Drum	Randolph AFB	Corpus Christi
57	Ft Hood	Reese AFB	Quantico
58	Ft Hunter Ligget	Robins AFB	Dahlgren
59	Ft Indiantown Gap	Scott AFB	Yorktown
60	Ft Irwin	Seymour Johnson AFB	Washington, DC
61	Ft Lewis	Shaw AFB	Whidbey Island
62	Ft McCoy	Sheppard AFB	Seattle
63	Ft McPherson	Tinker AFB	Allegany
64	Ft Meade	Travis AFB	
65	Ft Ord	Tyndall AFB	
66	Ft Pickett	Vance AFB	
67	Ft Polk	Vandenberg AFB	
68	Ft Riley	Warren AFB	
69	Ft Sam Houston	Wright-Patterson AFB	
70	Ft Sheridan		
71	Ft Stewart		

	Army	Air Force	Navy
72	Hunter AAF		
73	Kelly Sup Fac		
74	Presidio of Monterey		
75	Presidio of San Francisco		
76	Fitzsimmons AMC		
77	Ft Detrick		
78	Walter Reed AMC		
79	Ft Ritchie		
80	Cameron Station		
81	Ft Belvoir		
82	Ft Leslie McNair		
83	Ft Myer		
84	MOT North Carolina		
85	MOT New Jersey		
86	Oakland Army Base		
87	Ft Greely		
88	Ft Richardson		
89	Ft Shafter		
90	Ft Wainwright		
91	Carlisle Barracks		
92	Ft Benjamin Harrison		
93	Ft Benning		
94	Ft Bliss		
95	Ft Chaffee		
96	Ft Dix		
97	Ft Eustis		
98	Ft Gordon		
99	Ft Hamilton		
100	Ft Huachuca		
101	Ft Jackson		
102	Ft Knox		
103	Ft Leonard Wood		
104	Ft Leavenworth		

	Army	Air Force	Navy
105	Ft Lee		
106	Ft McClellan		
107	Ft Monroe		
108	Ft Rucker		
109	Ft Sill		
110	West Point Military Academy		

Although the database does not contain all DOD installations, REEP captures 97.19 percent of the total Army square footage in CONUS.

Installation Input Requirements

Table 2 lists the information required to describe an installation in REEP. Some of the information is readily available from published sources such as the *Facilities Engineering and Housing Annual Summary of Operations - Volume III - Installation Performance* (USAEHSC 1992, commonly known as the Red Book). The weather information was obtained from Engineering Weather Data (Department of the Army Technical Manual [TM] 5-785) and other miscellaneous sources. Some of the cells of information were generated from algorithms developed at USACERL, and much of the Air Force and Navy information was from their real-property tapes. All the information for this database required a substantial amount of effort to obtain, massage into a usable format, and load into a database file. Appendix A lists sources for real property and infrastructure data, and Appendix B provides background on sources of information on installation and utilities. Appendix C contains sources sources for location-specific weather data used in the REEP model.

Table 2. Installation information required in REEP.

	Description	Units
1	Service - i.e., Army, Navy, or Air Force	Dimensionless
2	Installation Name	Dimensionless
3	Major Command	Dimensionless
4	Population served	Persons
5	Thousands of gallons* of water used	K Gal

* A table of metric conversions can be found at p 68.

	Description	Units
6	Total cost of water service	Dollars
7	Unit cost of water service	Dollars
8	Thousands of linear feet of water distribution lines	KLF
9	Thousands of gallons of waste water treated	K Gal
10	Total cost of sewer services	Dollars
11	Unit cost of sewer services	Dollars
12	Annual MWH consumed	MWH
13	Total annual electrical cost	Dollars
14	Unit cost of electrical services	Dollars/MWH
15	Total annual cost for gas, oil, and coal	Dollars
16	Total square footage of facilities on installation	KSF
17	Gas heating/boiler plants over 3.5 MBtu/Hr capacity	MBtu/Hr
18	Gas heating/boiler plants over 3.5 MBtu/Hr consump.	MBtu
19	Oil heating/boiler plants over 3.5 MBtu/Hr capacity	MBtu/Hr
20	Oil heating/boiler plants over 3.5 MBtu/Hr consump.	MBtu
21	Coal heating/boiler plants over 3.5 MBtu/Hr capacity	MBtu/Hr
22	Coal heating/boiler plants over 3.5 MBtu/Hr consump.	MBtu
23	Gas heating plants .75 - 3.5 MBtu/Hr capacity	MBtu/Hr
24	Gas heating plants .75 - 3.5 MBtu/Hr consumption	MBtu
25	Oil heating plants .75 - 3.5 MBtu/Hr capacity	MBtu/Hr
26	Oil heating plants .75 - 3.5 MBtu/Hr consumption	MBtu
27	Coal heating plants .75 - 3.5 MBtu/Hr capacity	MBtu/Hr
28	Coal heating plants .75 - 3.5 MBtu/Hr consumption	MBtu
29	Gas heating plants under .75 MBtu/Hr capacity	MBtu/Hr
30	Gas heating plants under .75 MBtu/Hr consumption	MBtu
31	Oil heating plants under .75 MBtu/Hr capacity	MBtu/Hr
32	Oil heating plants under .75 MBtu/Hr consumption	MBtu
33	Coal heating plants under .75 MBtu/Hr capacity	MBtu/Hr
34	Coal heating plants under .75 MBtu/Hr consumption	MBtu
35	Total capacity of AC & chilled water plants >100 tons	Tons
36	Total capacity of AC & chilled water plants 5-100 tons	Tons
37	Total capacity of AC & chilled water plants <5 tons	Tons
38	Thousands of square feet of training facilities	KSF

	Description	Units
39	Thousands of square feet of maintenance facilities	KSF
40	Thousands of square feet of R & D facilities	KSF
41	Thousands of square feet of storage facilities	KSF
42	Thousands of square feet of hospital/medical facilities	KSF
43	Thousands of square feet of administrative facilities	KSF
44	Thousands of square feet of barracks facilities	KSF
45	Thousands of square feet of commercial facilities	KSF
46	Thousands of square feet of family housing facilities	KSF
47	Thousands of square feet of other facilities	KSF
48	Adjacent or nearest city to installation	City
49	State installation is located	State
50	Latitude - degrees	Degrees
51	Latitude - minutes	Minutes
52	Longitude - degrees	Degrees
53	Longitude - minutes	Minutes
54	Elevation of installation	Feet
55	Annual Heating Degree Days	F*day/year
56	Annual Cooling Degree Days	F*day/year
57	Winter Dry Bulb 97.5% design temperature	F
58	Summer Dry Bulb 2.5% design temperature	F
59	Mean Coincident Wet Bulb	F
60	Mean Daily Range	F
61	Annual average Btu/sf/day insolation	Btu/sf/day
62	Vertically transmitted radiation per degree day	Btu/SF/DD
63	Hours above 80 F dry bulb	Hours
64	Hours above 67 F wet bulb	Hours
65	Does Installation qualify for A/C? 1=Yes, 0=No	Dimensionless
66	Annual # of hrs. in 60/64 DB bin and up	Hours
67	Annual # of hrs. in 80/84 DB bin and up	Hours
68	Annual # of hrs. in 85/89 DB bin and up	Hours
69	Mean Coincident Wet Bulb for 80/84 DB bin	F
70	Mean Coincident Wet Bulb for 85/89 bin	F
71	ORNL cooling solar reflectance values	Dimensionless

	Description	Units
72	ORNL heating solar reflectance values	Dimensionless
73	Rundquist fraction of lighting heat to cooling	Dimensionless
74	Rundquist fraction of lighting heat to heating	Dimensionless
75	Lineal feet of Steam & HW distribution systems	KLF
76	Ground temperature	F
77	Hours of heating per year	Hours
78	Hours of cooling per year	Hours
79	Hours of heating per year for family housing	Hours
80	Days per year that heating is required	Days
81	Days per year that cooling is required	Days
82	Location indices used to localize construction costs	Dimensionless
83	1992 $/Kw inflated, escalated, and converted	$/MBtu
84	Annualized demand costs	$/kW
85	1992 DEIS gas cost inflated and escalated	$/MBtu
86	Oil cost	$/MBtu
87	1992 DEIS coal cost	$/MBtu
88	Marginal elec. cost from utility rate book	$/kWh
89	Installations peak electrical demand	kW
90	ECIP discount factor table identifier	Dimensionless
91	% of elec. produced by coal	%
92	% of elec. produced by petroleum	%
93	% of elec. produced by natural gas	%
94	% of elec. produced by hydroelectric	%
95	% of elec. produced by nuclear	%
96	% of elec. produced by misc. sources	%
97	Tons of CO2 produced by consuming 1 MBtu	tons/MBtu
98	Tons of SO2 produced by consuming 1 MBtu	tons/MBtu
99	Tons of NOX produced by consuming 1 MBtu	tons/MBtu
100	Tons of CO produced by consuming 1 MBtu	tons/MBtu
101	Tons of VOCs's produced by consuming 1 MBtu	tons/MBtu
102	Tons of Particulate Matter produced by consuming 1 MBtu	tons/MBtu
103	Annual MWH's of purchased electric	MWH
104	Microclimate cooling energy savings	%

	Description	Units
105	Microclimate peak reduction	%
106	Microclimate heating energy savings	%
107	# of exterior lights	# of lights
108	Wind power class for installation's location	Dimensionless

Additionally, there are 78 more cells of information for each installation that contain market penetration factors for each ECO. These market penetration factors predict the degree of penetration of each technology at each installation. A value of one (1.00) would indicate all opportunities have been realized, and a value of zero (0.00) would indicate that none of the potential opportunities have been accomplished. Most of the technologies selected for REEP do not have a high degree of penetration.

ECOs/WCOs in REEP

Table 3 lists the ECOs and WCOs in REEP in eight general categories: electrical, building envelope, HVAC, lighting, miscellaneous, renewables, utilities, and water. Chapter 5 provides detailed information for each ECO/WCO.

Table 3. ECOs/WCOs in REEP.

	ECO/WCO TYPE	ECO/WCO	UNIT
1	Electrical	High Eff Motors (Large)	Motors
2	Electrical	High Eff Motors (Medium)	Motors
3	Electrical	High Eff Motors (Small)	Motors
4	Electrical	Ventln Motor ASD (Large)	Motors
5	Electrical	Ventln Motor ASD (Medium)	Motors
6	Electrical	Ventln Motor ASD (Small)	Motors
7	Envelope	6.5 Inch Addtnl Clg Insul	Sq. Ft.
8	Envelope	Ext Insul Finish Sys	Sq. Ft.
9	Envelope	FH 6.0 Inch Addtnl Clg Insul	Sq. Ft.
10	Envelope	FH Rockwool Wall Insulation	Sq. Ft.
11	Envelope	High Reflctnce Roof Membrn	Sq. Ft.
12	Envelope	Radiant Barriers	Sq. Ft.
13	Envelope	Shading Devices	Sq. Ft.

	ECO/WCO TYPE	ECO/WCO	UNIT
14	Envelope	Storm Windows	Sq. Ft.
15	Envelope	Window Film	Sq. Ft.
16	Heating/Cooling	Enthalpy Recvry Desscnt Wheel	Wheels
17	Heating/Cooling	Evap. Pre-Cool Air	Units
18	Heating/Cooling	FH Desuperheaters	Desprhtrs
19	Heating/Cooling	FH Duct Seals	Houses
20	Heating/Cooling	FH Flame Ret. Burners	Burners
21	Heating/Cooling	FH Gas Engine Drvn HP	Heat Pumps
22	Heating/Cooling	FH Ground Source HP	Heat Pumps
23	Heating/Cooling	FH Heat Pumps	Heat Pumps
24	Heating/Cooling	FH HiEff Gas Furn	Furnaces
25	Heating/Cooling	FH HiEff Oil Furn	Furnaces
26	Heating/Cooling	FH High SEER AC	ACs
27	Heating/Cooling	FH Insulate Ducts	Sq. Ft.
28	Heating/Cooling	FH Nom Eff Gas Furn	Furnaces
29	Heating/Cooling	FH Progrmmbl Thermostats	Thermstats
30	Heating/Cooling	FH Whole House Fans w/AC	Fans
31	Heating/Cooling	Flame Retention Burners	Burners
32	Heating/Cooling	Gas Hieff Boilers	Boilers
33	Heating/Cooling	Gas Nomeff Boiler	Boilers
34	Heating/Cooling	Oil Nomeff Boiler	Boilers
35	Heating/Cooling	SLDC Panels	Panels
36	Heating/Cooling	Ventilation Heat Recovery	Heat Exchs
37	Lighting	4' Fluorescent Ltng	Fixtures
38	Lighting	Compact Fluorescent Ltng	Lamps
39	Lighting	Constant Level Lighting	Contrllrs
40	Lighting	Exit Lighting	Fixtures
41	Lighting	High Pressure Sodium Lghts	Lamps
42	Lighting	High wattage incand replcmnt	Fixtures
43	Lighting	Occupancy Sensor	Sensors
44	Miscellaneous	Efficient Computers	Computers
45	Miscellaneous	High Eff Refrig Replcmnt	Refrgrtrs
46	Renewables	Barracks Solar Water Htg	Barracks

	ECO/WCO TYPE	ECO/WCO	UNIT
47	Renewables	FH Passive Solar Sunspace	Rooms
48	Renewables	FH Solar Water Htg	Houses
49	Renewables	Microclimate Modifications	Houses
50	Renewables	Photovoltaic Peaking Station	Kw
51	Renewables	Solar Street Lighting	Fixtures
52	Renewables	SolarWall for Maint Bldgs	Sq. Ft.
53	Renewables	Wind Energy	Turbines
54	Utilities	Amorphs Core Transfrmrs	KVAR
55	Utilities	DF NG Chllrs >100 Tons	Chillers
56	Utilities	DF NG Chllrs 5-50 Tons	Chillers
57	Utilities	DF NG Chllrs 50-100 Tons	Chillers
58	Utilities	EMCS	Points
59	Utilities	GasEng Chllrs >100 Tons	Chillers
60	Utilities	GasEng Chllrs 5-50 Tons	Chillers
61	Utilities	GasEng Chllrs 50-100 Tons	Chillers
62	Utilities	HiEff Chllrs >100 Tons	Chillers
63	Utilities	HiEff Chllrs 5-50 Tons	Chillers
64	Utilities	HiEff Chllrs 50-100 Tons	Chillers
65	Utilities	Manhl Sump-Pmp I/R Prgrm	Units
66	Utilities	Storage Cooling Systems	Ton-Hours
67	Utilities	Undrgrnd Heat Dist Sys Rprs	Repairs
68	Water	Faucet Aerators	Aerators
69	Water	FH Hot Water Heat Pump	Heat Pumps
70	Water	FH Low Flow Toilets	Toilets
71	Water	FH Tankless Water Heaters	Heaters
72	Water	FH Ultra Low Flow Toilets	Toilets
73	Water	Flush Valve Retrofits	Valves
74	Water	Horizntl Axis Washng Mchns	Machines
75	Water	Low-flow Shower Head	Shwr Heads
76	Water	Water Consrvng Dishwshrs	Dishwshrs
77	Water	Water Distibtn Leak Repair	Repairs
78	Water	Wtr Htr Insulation Blanket	Blankets

Matrix of ECO/WCO vs. Building Type

Table 4 is an overview of which ECOs/WCOs are applied to certain types of facilities. Most of the conservation opportunities only map into a limited set of building types and are not applicable across the board. Furthermore, when an ECO/WCO is applied to a building type, frequently it is applied only to a certain percentage of the total square footage in that building category. To examine the specifics of how an ECO/WCO is applied to a certain building type, refer to the detailed writeups for each ECO/WCO in Chapter 5.

Table 4. ECO/WCO applications.

	ECO/WCO	Trng	M&P	R&D	Strg	H&M	Admin	UEPH	Comty	FH	Other
1	High Eff Motors (Large)	X				X	X	X	X		
2	High Eff Motors (Medium)	X				X	X	X	X		
3	High Eff Motors (Small)	X				X	X	X	X		
4	Ventln Motor ASD (Large)	X				X	X	X	X		
5	Ventln Motor ASD (Medium)	X				X	X	X	X		
6	Ventln Motor ASD (Small)	X				X	X	X	X		
7	6.5 Inch Addtnl Clg Insul	X					X				
8	Ext Insul Finish Sys	X					X	X	X		
9	FH 6.0 Inch Addtnl Clg Insul									X	
10	FH Rockwool Wall Insulation									X	
11	High Reflctnce Roof Membm	X					X			X	
12	Radiant Barriers	X					X			X	
13	Shading Devices	X					X	X			
14	Storm Windows	X					X	X			
15	Window Film	X					X	X			
16	Enthalpy Recvry Desscnt Wheel	X		X		X	X	X	X		
17	Evap. Pre-Cool Air	X		X		X	X	X	X		
18	FH Desuperheaters									X	
19	FH Duct Seals									X	
20	FH Flame Ret. Burners									X	
21	FH Gas Engine Drvn HP									X	
22	FH Ground Source HP									X	
23	FH Heat Pumps									X	
24	FH HiEff Gas Furn									X	
25	FH HiEff Oil Furn									X	
26	FH High SEER AC									X	

	ECO/WCO	Trng	M&P	R&D	Strg	H&M	Admin	UEPH	Comty	FH	Other
27	FH Insulate Ducts									X	
28	FH Nom Eff Gas Furn									X	
29	FH Progrmmbl Thermostats									X	
30	FH Whole House Fans w/AC									X	
31	Flame Retention Burners							X			
32	Gas Hieff Boilers										X
33	Gas Nomeff Boiler										X
34	Oil Nomeff Boiler										X
35	SLDC Panels	X		X		X	X	X	X		
36	Ventilation Heat Recovery	X		X		X	X	X	X		
37	4' Fluorescent Ltng	X	X	X	X	X	X	X	X		
38	Compact Fluorescent Ltng	X	X	X	X	X	X	X	X	X	
39	Constant Level Lighting						X				
40	Exit Lighting	X		X		X	X	X	X		
41	High Pressure Sodium Lghts	X	X		X				X		
42	High wattage incand replcmnt	X	X	X	X	X	X	X	X		
43	Occupancy Sensor	X		X		X	X		X		
44	Efficient Computers	X		X			X				
45	High Eff Refrig Replcmnt									X	
46	Barracks Solar Water Htg							X			
47	FH Passive Solar Sunspace									X	
48	FH Solar Water Htg									X	
49	Microclimate Modifications									X	
50	Photovoltaic Peaking Station										X
51	Solar Street Lighting										X
52	SolarWall for Maint Bldgs		X								
53	Wind Energy										X
54	Amorphs Core Transfrmrs	X	X		X	X	X	X	X	X	
55	DF NG Chllrs >100 Tons										X
56	DF NG Chllrs 5-50 Tons										X
57	DF NG Chllrs 50-100 Tons										X
58	EMCS	X		X		X	X	X	X	X	
59	GasEng Chllrs >100 Tons										X
60	GasEng Chllrs 5-50 Tons										X
61	GasEng Chllrs 50-100 Tons										X
62	HiEff Chllrs >100 Tons										X
63	HiEff Chllrs 5-50 Tons										X
64	HiEff Chllrs 50-100 Tons										X

	ECO/WCO	Trng	M&P	R&D	Strg	H&M	Admin	UEPH	Comty	FH	Other
65	Manhl Sump-Pmp I/R Prgrm										X
66	Storage Cooling Systems										X
67	Undrgrnd Heat Dist Sys Rprs										X
68	Faucet Aerators									X	
69	FH Hot Water Heat Pump									X	
70	FH Low Flow Toilets									X	
71	FH Tankless Water Heaters	X					X		X	X	
72	FH Ultra Low Flow Toilets									X	
73	Flush Valve Retrofits	X		X		X	X	X	X		
74	Horizntl Axis Washng Mchns									X	
75	Low-flow Shower Head									X	
76	Water Consrvng Dishwshrs									X	
77	Water Distibtn Leak Repair										X
78	Wtr Htr Insulation Blanket	X					X		X	X	

REEP Output Fields

Table 5 lists the columns of output produced by a REEP Simple Analysis. A convenient way to examine the algorithms for each field of output is to perform a Simple Analysis, view the Simple Output on-line, and use the help facility. Placing the cursor on the field of interest and pressing the F2 function key invokes the help facility, which displays the algorithm used to generate the displayed value.

Table 5. REEP Simple Analysis output.

	Column Description	Units	Output Column Heading
1	Installation		ins
2	Major Command		mac
3	ECO Type		ecotype
4	ECO		eco
5	ECO Group		ecogroup
6	Program Name		program
7	Number of ECO Units		numecouni
8	Initial Cost	Dollars	inicos
9	Heating Energy Saved	MBtu/Yr	heaenesav
10	Cooling Energy Saved	MBtu/Yr	cooenesav
11	Total Energy Saved	MBtu/Yr	totenesav

	Column Description	Units	Output Column Heading
12	Electricity Fuel Saved	MBtu/Yr	elefuesav
13	Demand Fuel Saved	Kw	demfuesav
14	Gas Fuel Saved	MBtu/Yr	gasfuesav
15	Oil Fuel Saved	MBtu/Yr	oilfuesav
16	Coal Fuel Saved	MBtu/Yr	coafuesav
17	Water Volume Saved	KGal	watvolsav
18	Electricity Cost Saved	Dollars/Yr	elecossav
19	Demand Cost Saved	Dollars/Yr	demcossav
20	Gas Cost Saved	Dollars/Yr	gascossav
21	Oil Cost Saved	Dollars/Yr	oilcossav
22	Coal Cost Saved	Dollars/Yr	coacossav
23	Water Cost Saved	Dollars/Yr	watcossav
24	HVAC Energy Cost Saved	Dollars/Yr	henecossav
25	HVAC Demand Cost Saved	Dollars/Yr	hdemcossav
26	Total Annual Cost Saved	Dollars/Yr	tanncossav
27	Sulfur Oxides Abated	Tons/Yr	soxaba
28	Nitrogen Oxides Abated	Tons/Yr	noxaba
29	Particulate Matter Abated	Tons/Yr	paraba
30	Carbon Monoxide Abated	Tons/Yr	coaba
31	Carbon Dioxide Abated	Tons/Yr	co2aba
32	Hydrocarbons Abated	Tons/Yr	hydaba
33	Construction Cost	Dollars	concos
34	Sight Inspection and Overhead Costs	Dollars	sio
35	Design Cost	Dollars	descos
36	Total Cost	Dollars	totcos
37	Salvage Value	Dollars	salval
38	Utility Rebate Percentage	% of IC	utirebper
39	Utility Rebate Amount	$/Unit or $/Kw	utirebamt
40	Total Investment	Dollars	totinv
41	Discount Factor Table	Dimensionless	disfactab
42	Annualized Electricity Savings	Dollars	annelesav
43	Electricity Discount Factor	Dimensionless	eledisfac
44	Electricity Discount Savings	Dollars	eledissav

	Column Description	Units	Output Column Heading
45	Annualized Gas Savings	Dimensionless	anngassav
46	Gas Discount Factor	Dollars	gasdisfac
47	Gas Discounted Savings	Dimensionless	gasdissav
48	Annualized Oil Savings	Dollars	annoilsav
49	Oil Discounted Savings	Dimensionless	oildisfac
50	Oil Discounted Savings	Dollars	oildissav
51	Annualized Coal Savings	Dimensionless	anncoasav
52	Coal Discount Factor	Dollars	coadisfac
53	Coal Discounted Savings	Dimensionless	coadissav
54	Annualized Demand Savings	Dollars	anndemsav
55	Demand Discount Factor	Dimensionless	demdisfac
56	Demand Discounted Savings	Dollars	demdissav
57	Total Discounted Savings	Dimensionless	totdissav
58	Annual Recurring Savings	Dollars	annrecsav
59	Discount Factor	Dimensionless	disfac
60	Discounted Savings	Dollars	dissav
61	Simple Payback	Years	simpay
62	Total Net Discounted Savings	Dollars	totnetdis
63	Savings to Investment Ratio	Ratio	sirrat
64	Adjusted Internal Rate of Return	Percent	adjintrat
65	Societal Electricity Cost	Dollars/Yr	socelecos
66	Societal Gas Cost	Dollars/Yr	socgascos
67	Societal Oil Cost	Dollars/Yr	socoilcos
68	Societal Coal Cost	Dollars/Yr	soccoacos
69	Societal Total Cost	Dollars/Yr	soctotcos
70	Technology Group		group
71	Rank Within Technology Group		rank

3 Description of Research

Diagram of REEP Structure

Figure 1 depicts where certain factors interact during REEP analysis. A brief description of each block in this diagram follows.

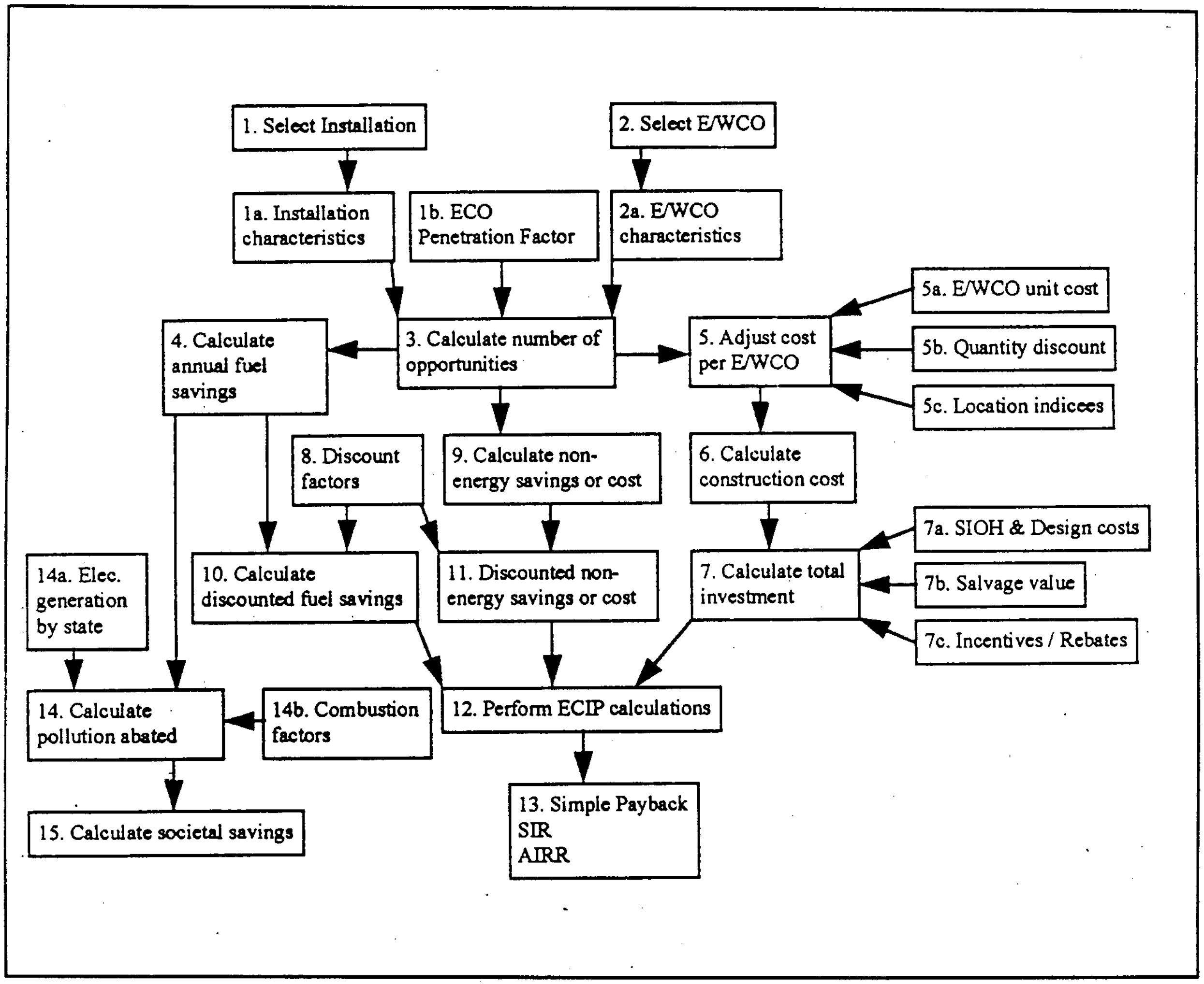


Figure 1. REEP analysis diagram.

1. Select Installation—For the execution of a REEP analysis, the user can select one or many installations. The selection of an installation is linked directly to the installation database, which contains installation characteristics (1a and 1b). Refer to Table 3 for a list of this information.

2. Select ECO/WCO—Selection of either an ECO or WCO causes the REEP program to activate ECO/WCO program files and an ECO/WCO database file. Each ECO and WCO has its own program file. These files contain *algorithms* unique to each technology. The ECO/WCO database file contains *values* and *variables* unique to each ECO/WCO.

3. Calculate Number of Opportunities—An algorithm unique to each technology resides in the ECO/WCO program file. This algorithm estimates the number of opportunities for each technology. These algorithms may vary considerably from one technology to another because one ECO may be estimating square footage of insulation, and another may be estimating the number of heating units, toilets, storm windows, etc.

4. Calculate Annual Fuel Savings—The program file for each ECO/WCO contains a series of algorithms that calculate gas, oil, coal, water, electrical, and demand savings. In most instances, only one or a few resource savings apply. The program file calls for data from the ECO and installation databases to perform these calculations.

5. Adjust Cost per ECO/WCO—ECO costs were obtained from a variety of sources and are adjusted depending on the size of the project (5b) and location (5c). Refer to **ECO E onom** page 34) for more information.

6. Calculate Construction Costs—Once the ECO unit cost has been adjusted, it is multiplied by the number of opportunities to calculate a construction cost for the project.

7. Calculate Total Investment—Currently the construction cost is increased by 6 percent site inspection and overhead (SIOH) and 6 percent design cost to calculate a total investment cost for a project.

8. Discount Factors—Nonfuel and fuel discount factors published by the National Institute of Standards and Technology (NIST) (Petersen, October 1993) are used to adjust annual fuel and non-energy savings for the economic analysis.

9. Calculate Non-Energy Savings or Costs—Periodic equipment upkeep or reduction or increases in labor or maintenance qualify as non-energy savings or costs. These costs need to be considered for the economic analysis. A good example is the decrease in maintenance required when going from incandescent to fluorescent lightbulbs. The long life of fluorescent bulbs reduces maintenance requirements and adds to the value of the ECO.

10. Calculate Discounted Fuel Savings—Annual fuel savings calculated in block 4 are multiplied by discount factors in block 8 to determine discounted fuel savings over the life of the ECO.

11. Discounted Non-Energy Savings or Cost—Nonfuel future single amounts or annually recurring amounts are multiplied by Single Present Value (SPV) or Uniform Present Value (UPV) discount factors in block 8 to determine discounted nonfuel savings over the life of the ECO.

12. Perform ECIP Calculations—The Energy Conservation Investment Program (ECIP) calculations are a series of algorithms that calculate simple payback, savings-to-investment ratios (SIRs), and adjusted internal rates of return (AIRRs). See pages 45 through 46 for more on these calculations.

13. ECIP Results—The results of the ECIP calculations are simple payback, SIRs and AIRRs. These values establish the economic indicators that show whether a project meets certain economic criteria.

14. Calculate Pollution Abated—The amount of pollution not created (abated) by saving energy is a function of several factors. The annual fuel savings, how the energy is consumed (e.g., the combustion efficiency of a piece of equipment [14b]) and, if electricity is involved, how the electricity is generated (14a). Refer to **Pollution Algorithms** (page 37) for an expanded discussion on this topic.

15. Calculate Societal Savings—Certain social benefits can be attributed to reductions in pollution generation rates. Once the amount of pollution abated through the implementation of an ECO has been calculated, and a monetary benefit per unit quantity is known, it is a simple calculation to determine societal savings. Refer to **Societal Costs Algorithms** (page 42) for an expanded discussion on this topic.

ECO Economics

The analysis of ECOs use current ECO costs and energy prices to provide a snapshot of each ECO's economic potential and ability to satisfy ECIP criteria. All dollar savings due to reduced energy consumption are based on current energy prices at each installation. The economics of many of the ECOs could change significantly if future energy prices fluctuate or if DSM rebates were taken into account. Important elements taken into account during the financial analysis are briefly described below.

ECO Costs

To arrive at the cost for each ECO, a cost per unit was first obtained from cost estimating books, construction estimators, or some other reputable source. These ECO costs were then adjusted to Washington, DC prices, which were then adjusted to costs at each installation using cost indices from Army Regulation (AR)415-17, Construction Cost Estimating for Military Programming. ECO costs are in the ECO database file and can be changed by a user if needed.

Location Indices

Each ECO's projected cost per installation was adjusted per AR415-17, Table 2—Location Adjustment Factors. These indices adjust Washington, DC prices to anticipated costs at individual installations. These values can be found in the Instdata database.

Recurring Costs

Each ECO has recurring costs associated with it that are specified as a percentage of the initial cost of the ECO. This cost is used in the SIR equations. In some instances, recurring costs were a negative value where an ECO would have reduced maintenance requirements, such as in the replacement of incandescent lamps with compact fluorescent lamps. However, in many instances, recurring costs were low because this cost was intended to reflect the differential recurring cost between the existing technology and the ECO technology, which in most instances was considered negligible.

Economic Life

The ECIP economic evaluation process used for the REEP model specifies life expectancies to be used in the economic calculations for various categories of project types. All projects have either a 10, 15, or 20 year life expectancy. Project life affects which discount factors to use in the economic calculations.

ECIP Criteria

ECIP is a subset of the Defense Agencies Military Construction (MILCON) program specifically designated for projects that save energy or reduce DOD energy costs. It includes construction of new, high-efficiency energy systems or the improvement and modernization of existing systems. ECIP criteria (OASD memorandum, 17 March 1993) specifies that for an ECO to qualify for funding, it must have a simple payback of 10 years or less, and have an SIR of 1.25 or greater. These criteria are used in the REEP model to filter ECOs. Only ECOs that meet these criteria are included in the results. However, the REEP model has been programmed so that a user can modify the Simple Payback and SIR filters if so desired.

Discount Factors

To follow ECIP calculations and discount fuel savings over the life of the ECO, discount factors for each installation were obtained from *Energy Prices and Discount Factors for Life-Cycle Cost Analysis 1994* (Petersen, October 1993), which breaks down the 50 states into four regions. The Modified Uniform Present Value Discount Factor adjusted for fuel price escalation, by end-use sector and fuel type, with a discount rate of 3.1 percent was extracted from Tables Ba-1 through Ba-4 of Peterson (October 1993). From each of these tables, the 10, 15, and 20 year industrial values were pulled for electricity, gas, oil, and coal. These factors are used in the REEP analysis to calculate discounted savings and costs for each of the various fuels as they apply to the different ECOs.

Simple Payback

Simple payback periods are calculated for all of the ECOs and for each installation. Payback periods can vary greatly from one installation to the next for a single ECO, primarily due to energy cost variations and climatic influences. Simple payback analysis is a rather simplistic way to gauge the economics of an ECO; however, if energy prices remain stable, it provides a rough idea of how fast capital costs will be recovered.

Simple Payback is calculated as follows:

$$\text{Simple Payback} = \frac{\text{Total Investment}}{\text{Total Annual Savings}}$$

where:

Simple Payback units are in years.

Total Investment = (# of ECOs × adjusted unit cost) + SIOH + design cost

Total Annual Savings = Annual resource savings ($) + Annual nonfuel savings ($) or cost

Savings to Investment Ratio

The SIR is one way to gauge the merits of an ECO over time. The SIR calculation uses discount factors to predict what the value of the fuel saved over time is worth. The SIR divides the total net discounted savings by the total investment of the ECO. Thus, if the total net discounted savings over the life of the project equal the cost of the project, the ECO has an SIR of 1.0. The old ECIP criteria stated that for projects to qualify for ECIP funding, they had to have an SIR of 1.0. This requirement, however, was recently revised so that a project now must have an SIR of 1.25 or greater.

SIR is calculated as follows:

$$\text{Savings Investment Ratio} = \frac{\text{Total Net Discounted Savings}}{\text{Total Investment}}$$

where:

Savings Investment Ratio is a dimensionless number.

Total Net Discounted Savings = Discounted resource savings over the life of the ECO + Discounted nonenergy savings over the life of the ECO

Total Investment = (# of ECOs × adjusted unit cost) + SIOH + design cost

Adjusted Internal Rate of Return

The AIRR provides a measure of return on investment of the project relative to other potential investments that can be made.

AIRR is calculated as follows:

$$AIRR = ((1 + d) \times SIR^{1/N} - 1) \times 100$$

where:

AIRR units are in percent.

SIR = Savings to Investment Ratio

d = Discount Rate (current 4.0 percent)

N = Economic Life

Pollution Algorithms

One of the objectives of REEP is to determine the amount of pollution offset by implementing each ECO/WCO. The amount and type of fuel saved by each ECO/WCO is calculated, and from our calculated rate estimates, tonnage of pollutants abated then can be determined. The REEP model outputs energy savings in the form of on-site fossil fuels and purchased electricity, which is derived from a variety of sources including gas, oil, coal, hydroelectric, and nuclear. With purchased electricity, only the fossil fuels are of interest when calculating pollution rates. Two distinct sets of algorithms are used to calculate pollution savings based on the energy type. The primary pollutants associated with fossil fuel combustion are: sulfur dioxide (SO_2), nitrogen oxides (NO_X), carbon monoxide (CO), carbon dioxide (CO_2), particulate matter (PM), and hydrocarbons (HC).

On-Site Fossil Fuel Pollution Estimates

When dealing with fossil fuels, a straightforward method is used. Using AP-42 (U.S. Environmental Protection Agency [USEPA], September 1991) in conjunction with the assumptions following Tables 6 and 7, controlled pollution estimates for fossil fuel energy savings were developed. Table 6 shows the controlled pollution estimates broken out by fossil fuel type. Controlled pollution abated is calculated based on the fuel savings calculated in the REEP model. Gas, oil, and coal savings can be directly converted into tonnage of pollutants abated for all six pollutant categories.

Table 6. Controlled pollution estimates for industrial boilers using gas, oil, or coal.

Pollutant	Gas (lb/MBtu)	Residual Oil (lb/MBtu)	Distillate Oil (lb/MBtu)	Oil (lb/MBtu)	Coal (lb/MBtu)
SO_2	0.00059	1.04667	0.5528169	0.68616	2.9444
NO_x	0.137	0.36667	0.1408450	0.20182	0.5840
CO	0.034	0.03333	0.0352112	0.03470	0.20856
CO_2	115	170	170	170	200
PM	0.003	0.08667	0.0140845	0.03368	0.03
HC	0.00058	0.008533	0.0004084	0.00260	0.00417

Table 7. On-site fossil fuel energy rates.

Gas MBtu/1000 ft^3	Residual Oil MBtu/Gal	Distillate Oil MBtu/Gal	Coal MBtu/ton
1.024798	0.150	0.142	23.974

Table 7 gives the 1992 national annual energy rate per fossil fuel source used for on-site pollution abatement calculations (Energy Information Administration [EIA], February 1994; EIA, August 1993a; Buonicore and Davis 1992).

sumptions

Coal purchased by the DOD was assumed to be bituminous and have a sulfur content of 1.81 percent.

- All residual oil was assumed to have a sulfur content of 1.0 percent, while distillate oil was assumed to have a sulfur content of 0.5 percent.
- Natural gas was assumed to have 3 lb of PM/10^6 cu ft of gas.
- When performing calculations from the AP-42, the DOD was assumed to use industrial boilers for oil and gas, while spreader stoker boilers were assumed for all coal.
- The oil pollution rates are a weighted average of rates from residual (27 percent) and distillate (73 percent) based on 1992 national consumption rates found in the Defense Energy Information System (DEIS*), in Army Regulation (AR) 11-27.
- Control technologies (baghouses or electrostatic precipitators) exist for coal fired boilers and reduce PM emissions to 0.03 lb/MBtu (Buonicore and Davis 1993; Savoie and Davidson, June 1991).

* DEIS is now DUERS (Defense Utility Energy Reporting System).

- The following formulae are examples of how a fossil fuel source is mapped into each pollutant. These algorithms were executed after the gas, oil, or coal savings were calculated for each ECO and WCO.

SO_2 = ECO Gas Savings (MBtu) × (0.00059 lb/MBtu) / (2,000 lb/ton)
SO_2 = ECO Oil Savings (MBtu) × (0.68616 lb/MBtu) / (2,000 lb/ton
SO_2 = ECO Coal Savings (MBtu) × (2.9444 lb/MBtu) / (2,000 lb/ton)

NO_x = ECO Gas Savings (MBtu) × (0.137 lb/MBtu) / (2,000 lb/ton)
NO_x = ECO Oil Savings (MBtu) × (0.20182 lb/MBtu) / (2,000 lb/ton)
NO_x = ECO Coal Savings (MBtu) × (0.5840 lb/MBtu) / (2,000 lb/ton)

CO = ECO Gas Savings (MBtu) × (0.034 lb/MBtu) / (2,000 lb/ton)
CO = ECO Oil Savings (MBtu) × (0.03470 lb/MBtu) / (2,000 lb/ton)
CO = ECO Coal Savings (MBtu) × (0.20856 lb/MBtu) / (2,000 lb/ton)

CO_2 = ECO Gas Savings (MBtu) × (115 lb/MBtu) / (2,000 lb/ton)
CO_2 = ECO Oil Savings (MBtu) × (170 lb/MBtu) / (2,000 lb/ton)
CO_2 = ECO Coal Savings (MBtu) × (200 lb/MBtu) / (2,000 lb/ton)

PM = ECO Gas Savings (MBtu) × (0.003 lb/MBtu) / (2,000 lb/ton)
PM = ECO Oil Savings (MBtu) × (0.03368 lb/MBtu) / (2,000 lb/ton)
PM = ECO Coal Savings (MBtu) × (0.03 lb/MBtu) / (2,000 lb/ton)

HC = ECO Gas Savings (MBtu) × (0.00058 lb/MBtu) / (2,000 lb/ton)
HC = ECO Oil Savings (MBtu) × (0.00260 lb/MBtu) / (2,000 lb/ton)
HC = ECO Coal Savings (MBtu) × (0.00417 lb/MBtu) / (2,000 lb/ton)

Purchased Electricity Pollution Estimates

While fossil fuels were straightforward for estimating pollution savings, electricity proved to be more challenging. How the electricity is produced (i.e., from gas, oil, coal, nuclear, or hydroelectric) is a critical issue when estimating pollution rates. Early attempts used national averages to break out fuel types. To improve the accuracy of REEP estimates, state averages were used (EIA, June 1994). Furthermore, different assumptions were used to obtain pollution estimates from end-user electricity savings. Efficiency of electricity production was assumed to be 28.5 percent (Energy Information Administration, August 1993b), which includes transmission losses, in plant use, and combustion losses. Utility-sized boilers were assumed rather than the industrial-sized boilers used in fossil fuel algorithms.

Table 8 shows the estimated end-user pollution rates of the fossil fuels used in generating electricity. Because SO_2 production depends on the sulfur content of the coal burned, our assumption used with fossil fuels on site was different than those applicable to a utility.

Table 8. Pollution estimates applied to electricity derived from gas, oil, or coal.

Pollutant	Gaslbs/MBtu	Oil lb/MBtu	Coal lb/MBtu
SO_2	regional	regional	regional
NOx	0.200	0.300	0.700
CO	0.039078	0.0331748	0.02886
CO_2	115	170	200
PM	0.00293	0.100	0.100
HC	0.0016608	0.0069003	0.00481

Table 9. Pollution estimates applied to electricity derived from gas, oil, or coal.

Region	SO_2 (lb/MBtu)	States in region
1	2.58460	CT, MA, ME, NH, RI, VT
2	2.19690	NJ, NY, PR, VI
3	5.29830	DC, DE, MD, PA, VA, WV
4	4.45835	AL, FL, GA, KY, MS, NC, SC, TN
5	6.71983	IL, IN, MI, MN, OH, WI
6	1.42150	AR, LA, NM, OK, TX
7	5.49217	IA, KS, MO, NE
8	2.13226	CO, MT, ND, SD, UT, WY
9	0.71075	AZ, CA, HI, NV
10	0.32307	AK, ID, OR, WA

The *EPA Green Lights* provides regional SO_2 estimates, which are aggregations of state pollution emission factors (USEPA, March 1994). Table 9 shows the regional SO_2 estimates and the states used in the REEP model. Other assumptions used are listed after Table 10.

Table 10. Utility fossil fuel energy rates.

Gas MBtu/100 cu ft	Oil MBtu/gal on	Coal MBtu/ton
1.0235958	0.1507168	20.790000

Table 10 provides 1992 national annual energy rates for fossil fuels used in the pollution calculations when applied to electrical savings (EIA, August 1993a).

Assumptions:

- Residual oil is assumed in all electricity oil pollution rates.
- Natural gas was assumed to have 3 lb of PM/10^6 cu ft of gas.

When performing calculations from the AP-42 (USEPA, September 1991), electric utilities were assumed to use utility boilers for oil and gas, while a dry bottom, pulverized coal fired boiler was assumed for all coal burning.

- Federal guidelines (40 CFR 60.40) which apply to PM, SO_2, and NOx are used as emission factors.
- Following is a sample formula used to determine the amount of pollution abated by electrical savings. These algorithms were executed after the electricity savings were calculated for each ECO and WCO.

NOx = Elec Savings (MBtu) x [(% Gas)(0.200 lb/MBtu) + (% Oil) (0.300 lb/MBtu) + (% Coal)(0.700 lb/MBtu)] / 2000 lb/ton / EFF

where:

(% Gas)	=	percentage of state's electricity produced from gas
(% Oil)	=	percentage of state's electricity produced from oil
(% Coal)	=	percentage of state's electricity produced from coal
EFF	=	overall efficiency of electricity production

- The marginal electrical energy saved was assumed to be divided equally between the different fossil fuels, nuclear, hydroelectric, and others. In reality, because coal is used to meet base demand and gas is used in meeting peak demands, gas theoretically, would dominate the fuel savings. Thus, because gas has lower emission rates, pollution and societal costs savings would decrease. This complexity was not addressed within the scope of the project. For the purpose of this model, the current pollution estimations were deemed adequate.

Wheeling on the electrical grid and on-site system efficiencies would have to be taken into account if an increasingly precise estimate of pollution offset were desired. REEP is more a high level scoping tool, so it was decided that issues such as wheeling would not be considered.

Societal Costs Algorithms

Recently, the true cost of energy has been under examination. Besides the actual fuel or electricity cost, environmental scientists are attempting to quantify the indirect or societal costs of using energy. Societal costs include the degradation of health, vegetation, and property associated with air pollution resulting from fossil fuel combustion. Analysis of various studies reveals that quantification of these costs varies with the region and the author's bias. In each study, all or some of the pollutants were used to estimate societal costs. Table 11 shows the variability in societal costs estimates from various studies (Consumer Energy Council of America Research Foundation, July 1993). Due to its nationalized focus, the Pace University study (Ottinger et al. 1990) was chosen for estimating societal costs in the REEP model. It is important to note that these societal cost rates for electric utilities are being used for all pollution savings calculated through REEP regardless of the energy source. This assumption is made because the societal rates are based on the pollutant, not the energy source.

Table 11. Societal cost estimates from various studies.

Study	SO_2 ($/lb)	NOx ($/lb)	PM ($/lb)	HC ($/lb)	CO ($/lb)	CO_2 ($/lb)
Pace University	2.030	0.8200	1.1900	-	-	0.0068
New York	0.637	3.0405	0.1665	-	-	0.0006
Massachusetts	0.850	3.6000	2.2000	3.070	0.480	0.0120
Nevada	0.822	3.5830	2.2030	0.738	0.485	0.0120
California	2.243	4.5600	1.3120	2.118	-	0.0042
Bonneville Power	0.790	0.4660	0.8120	-	-	0.0032
Wisconsin	-	-	-	0.075	-	0.0075
Source: Consumer Energy Council of America, July 1993.						

Mutually Exclusive Technologies

For certain instances in the REEP project, several ECOs applied to the same situation. For example, each family housing unit only requires one heating and cooling system; however, five different means to heat and four different means to cool were analyzed. Similarly, both radiant barriers and high reflectance roof surfaces would not be applied to the same building. These are mutually exclusive technologies. The REEP program has been structured to avoid overlap of ECOs and taking multiple credits for a situation that can only have one solution. For the following instances, multiple ECOs were analyzed:

- Family housing heating and cooling plants—five heating, and four cooling technologies

- Domestic water heating technologies—three technologies
- Mitigate infrared radiation transfer through glazed surfaces—three technologies
- Mitigate infrared radiation transfer through roof surfaces—two technologies
- Alternatives for efficient street lighting—two technologies.

The REEP program is structured so that a user can select from a set of output variables that are used as the criteria to compare one ECO to another. This comparison is only in effect for summary and composite reports. See **Analysis Results** for examples of these reports. During a Simple Analysis, all selected technologies are evaluated whether they compete with one another or not. These results are used to generate the summary and composite reports.

Following is the list of output variables that the selection criteria can be based on. The program's default setting is set to Simple Payback, meaning that the ECO with the quickest payback would take precedence over all other competing ECOs. The Y (Yes) and N (No) designator next to the output variable shows how a user selects which variables to use for the selection criteria.

Simple Payback	Y
Savings to Investment Ratio	N
Adjusted Internal Rate of Return	N
Total Investment	N
Total Net Discounted Savings	N
Annual Savings	N
Electric Energy Saved	N
Gas Energy Saved	N
Oil Energy Saved	N
Coal Energy Saved	N
Total Energy Saved	N
Demand Energy Saved	N
Water Volume Saved	N
Sulfur Oxides Abated	N
Nitrogen Oxides Abated	N
Particulate Matter Abated	N
Carbon Monoxide Abated	N
Carbon Dioxide Abated	N
Hydrocarbons Abated	N
Chlorofluorocarbons (CFCs) Displaced	N

The REEP program was structured in this way so users would not be constrained by how one technology is selected over another. Users may not want the program to

select technologies based on financial criteria, but rather on energy savings or the amount of pollution abated. In some instances, certain technologies have a faster payback than others, but do not save as much energy as another technology. The capability to change selection criteria allows the user to examine results based on their own concerns.

Family Housing Heating/Cooling ECO Evaluation

The selection of a family housing heating and cooling system is somewhat more complex than simply comparing one simple output variable. This is because certain systems provide both heating and cooling (i.e., heat pumps) and other systems only perform one function, heating or cooling.

To begin with, all heat pump program files perform a check to see if an installation qualifies for air conditioning. If not, the heat pump systems are not evaluated at those installations. At installations with no air conditioning, only the systems that provide heating are evaluated. These systems are:

1. High efficiency gas furnace
2. Nominal efficiency gas furnace
3. Flue dampers/electronic ignition
4. High efficiency oil furnace
5. Flame retention burners.

If gas is being consumed at an installation in the under 0.75 MBtu/hr bin in Instdata, it is assumed that family housing has gas heat and the first three systems listed above are evaluated. Similarly, if oil is being consumed at an installation in the under 0.75 MBtu/hr bin in Instdata, it is assumed that family housing has oil heat and systems 4 and 5 are evaluated.

When the high efficiency furnace is compared with the nominal efficiency gas furnace, the nominal efficiency furnace beats the high efficiency furnace from a financial standpoint because of its substantially lower cost, but not from an energy savings standpoint, although both may satisfy ECIP criteria. In situations such as this, where both options meet ECIP criteria, the user may want to filter results on total energy savings rather than financial results. The flue damper/electronic ignition retrofit option is considered a "last-resort" retrofit if both high efficiency and nominal efficiency gas furnaces do not meet ECIP criteria. However, when executing the program, the user must be careful to ensure that the flue damper/electronic ignition retrofit option does not override the other options simply because of its financial attributes.

Although it may have a short payback period and high SIR, it is still considered a marginal energy saving solution.

Selection of an HVAC system for family housing at installations in climates that qualify for air conditioning is somewhat more complex than at installations that do not qualify for air conditioning because there are more systems and combinations of options available to analyze and compare to one another in climates that qualify for air conditioning. The available system options include:

1. High efficiency gas furnace
2. Nominal efficiency gas furnace
3. Gas engine driven heat pump
4. Electric heat pump
5. Ground source heat pump
6. Flue dampers/electronic ignition
7. High SEER air conditioner (AC)
8. High efficiency oil furnace
9. Flame retention burners.

In this situation, all of the technologies are evaluated independently in the Simple Analysis. For the comparison, the heat pumps are compared to:

- the high efficiency gas furnace plus the high SEER AC unit
- the nominal efficiency gas furnace plus the high SEER AC unit
- the existing system retrofit with flue dampers and electronic ignition plus the high SEER AC unit.

Although this is a simplistic approach to comparing systems, REEP was only developed to be used as a scoping tool and this approach was deemed sufficient.

Small, Medium, and Large Chiller Options

Three types of mechanical cooling systems—high efficiency electric chillers, direct fired gas absorption chillers, and gas engine-driven chillers—can be analyzed in three size ranges: 5 to 50 tons, 50 to 100 tons, and greater than 100 tons. All three cooling system options are analyzed in the Simple Analysis and an option selected for the summary or composite report based on the technology that best satisfies the selection criteria chosen.

Modular Boiler Options

Two types of modular boiler heating systems—pulse combustion and nominal efficiency boilers—can be analyzed with REEP. These boilers are intended to replace older, inefficient gas-fired hot water boilers in the size range of 0.5 to 1.5 MBtu/hr. Both options are analyzed in the Simple Analysis and an option selected for the summary or composite report based on the technology that best satisfies the selection criteria chosen.

Building System Control Technology Options

Two building system controls can be analyzed using REEP, an Energy Monitoring Control System (EMCS) and a Single-Loop Digital Control (SLDC) system. Both options are analyzed in the Simple Analysis and an option selected for the summary or composite report based on the technology that best satisfies the selection criteria chosen.

Domestic Water Heating ECO Options

REEP contains three family housing water heating technology options: solar water heating, hot water heat pump, and instantaneous hot water heater. All three options are analyzed in the Simple Analysis and an option selected for the summary or composite report based on the technology that best satisfies the selection criteria chosen

Mitigate Infrared Radiation Transfer Through Glazed Surfaces

To reduce cooling loads imposed by solar gains through glazed surfaces, three strategies were evaluated: application of films on the interior surface of windows, installation of solar shading screens on the exterior, and microclimate modifications. Microclimate modifications entail the planting of trees to intercept solar radiation. To contend with the potential overlap of window films, solar shading screens, and microclimate modifications, the REEP program performs the analysis of each, and an option selected for the summary or composite report based on the technology that best satisfies the selection criteria chosen.

Mitigate Infrared Radiation Transfer Through Roof Surfaces

To reduce cooling loads imposed by solar gains through roof surfaces, two technologies were evaluated: high reflectance roof surfaces and radiant barriers. Both of these ECOs were applied to the same building types. Rather than apply an evaluation

hierarchy to these competing technologies, each ECO was applied to only 30 percent of the square footage of each applicable building type. The reason for this is that, in certain situations, such as on buildings with sloped roofs with attic spaces, radiant barriers would be the desirable solution; however, on buildings with flat roofs, a high reflectance roof membrane would be desirable. Thus, because building configurations on installations are mixed, and both technologies are only applied to 30 percent of the buildings, it can be assumed that the approach used to analyze these ECOs eliminates potential overlap.

Efficient Street Lighting Options

Two alternatives were evaluated for efficient street lighting: (1) relamp existing fixtures with high pressure sodium lamps and (2) replace the entire lighting fixture with a solar powered unit. The solar powered street lights would be more applicable to new construction where a credit could be taken for not having to run the infrastructure required for conventional street lights.

4 Using the Reep Program

The REEP program is a flexible analysis tool that allows you to perform "what if" types of analyses. You may, at any time, make changes to any of the data in the system.

Warning: As with all computer systems, the GIGO (garbage in - garbage out) principle is in effect. If unreasonable numbers are entered into the system or a value is miss-keyed the results will not be reliable. Extra caution should be exercised when changing the data in this system.

Installing REEP

Before attempting to install REEP, at least 4 megabytes of space must be available on the computer's hard drive. To install REEP on your hard drive, follow these seven steps:

1. Make sure Windows™ is running.
2. Place REEP Disk 1 in drive A. If your source drive is drive B, improvise accordingly.
3. In Windows, choose the FILE option in the Windows Program Manager.
4. Select the RUN option.
5. When prompted, type in: a:setup (or b:setup if you are using the B drive).
6. Additional instructions will be provided while the setup routine is running (e.g., when to insert REEP Disk 2, etc.). Follow all instructions carefully.
7. After the setup routine is finished, store the original REEP diskettes in a safe place.

Installations

Six basic operations can be performed under the Installations option: installations for analysis, modify installations, add installations, delete installations, view installations, and print installations.

Selecting Installations for Analysis

1. Select the Select for Analysis option from under the main Installations menu bar.
2. Select either Army, Navy, Air Force, Marines, or ALL.
3. When the Select Installation(s) for Analysis popup appears, select the installation to be included in the REEP analysis. If you would like to include more than one installation, hold down the Control key while clicking on the desired installations.
4. After all the desired installations have been selected, press the F12 key to accept the choices.

Modifying Installations

1. Select the Modify option from under the main Installations menu bar.
2. Select either Army, Navy, Air Force, or Marines.
3. When the Modify Installation(s) window appears, make the desired changes to the installation you are interested in.
   - use the arrow keys to highlight the field
   - type in the desired value
   - when finished, close the window by clicking on the button in the upper left corner of the window and selecting the Close option.

Adding Installations

1. Select the Add option from under the main Installations menu bar.
2. Select either Army, Navy, Air Force, or Marines.
3. When the Add Installation(s) window appears, add the information for the installation in the fields provided.
   - use the arrow keys to highlight the field
   - type in the desired value
   - when finished, close the window by clicking on the button in the upper left corner of the window and selecting the Close option.

Deleting Installations

1. Select the Delete option from under the main Installations menu bar.
2. Select either Army, Navy, Air Force, or Marines.
3. When the Delete Installation(s) window appears, click on the vertical, rectangular button to the immediate left of the installation you would like to delete. A selected button will appear darkened, which indicates that the installation has

been marked for deletion. Unmark an installation by clicking on the same button again.

4. When finished, close the window by clicking on the button in the upper left corner of the window and selecting the Close option. Any installations marked for deletion will be removed from the database.

Viewing Installations

1. Select the View option from under the main Installations menu bar.
2. Select either Army, Navy, Air Force, or Marines.
3. When the Select Installation to View popup appears, click on the installation to be viewed.
4. After the desired installation has been selected, press the F12 key to accept your choice.

Note: Although the program will allow selection of more than one installation for viewing, only the first one selected will be displayed.

Printing Installations

1. Select the Print option from under the main Installations menu bar.
2. Select either Army, Navy, Air Force, or Marines.
3. When the Select Installation to Print popup appears, click on the installation to be printed.
4. Press the F12 key to accept your choice.

Note: Although the program will allow selection of more than one installation for printing, only the first one selected will be printed out.

ECOs

Under the ECOs option, six basic operations can be performed:

- select ECOs for analysis
- modify ECO assumptions and rules
- add ECO assumptions
- delete ECO assumptions
- view ECO assumptions
- print ECO assumptions.

Appendix D includes algorithms for each ECO.

Selecting ECOs for Analysis

1. Select the Select for Analysis option from under the main ECOs menu bar.
2. Select either Electrical, Envelope, Heating/Cooling, Lighting, Miscellaneous, Renewables, Utilities, Water, or All, depending on the type of ECO to be included in the analysis.
3. When the Select ECO(s) for Analysis popup appears, select the ECO you would like to include in the REEP analysis. If you would like to include more than one ECO, hold down the Control key while clicking on the desired ECOs.
4. After all the desired ECOs have been selected, press the F12 key to accept your choices.

Modifying ECO Assumptions and Rules

1. Select the Modify option from under the main ECOs menu bar.
2. Select either Electrical, Envelope, Heating/Cooling, Lighting, Miscellaneous, Renewables, Utilities, or Water, depending on the type of ECO to be modified.
3. When the Select ECO to Modify popup appears, select the ECO that you would like to modify by clicking on it with your mouse.
4. After the selection has been made, press the F12 key to accept your choice.
5. When the Modify ECO window appears, make the desired changes to the ECO and the associated rules file.
   - use the arrow keys to highlight the assumption field
   - type in the desired value
   - to modify the rules (developers only), use the standard Windows editing commands
   - when finished making changes, press the F12 key.

Adding ECO Assumptions

1. Select the Add option from under the main ECOs menu bar.
2. Select either Electrical, Envelope, Heating/Cooling, Lighting, Miscellaneous, Renewables, Utilities, or Water, depending on the type of ECO to be added.
3. When the Add ECO Assumption(s) window appears, add the assumptions for the ECO in the fields provided.
   - use the arrow keys to highlight the field
   - type in the desired value
   - when finished, close the window by clicking on the button in the upper left corner of the window and selecting the Close option.

Deleting ECO Assumptions

1. Select the Delete option from under the main ECOs menu bar.
2. Select either Electrical, Envelope, Heating/Cooling, Lighting, Miscellaneous, Renewables, Utilities, or Water, depending on the type of ECO to be deleted.
3. When the Delete ECO Assumption(s) window appears, click on the vertical, rectangular button to the immediate left of the ECO you would like to delete. A selected button will appear darkened, which indicates that the ECO has been marked for deletion. Unmark an ECO by clicking on the same button again.
4. When finished, close the window by clicking on the button in the upper left corner of the window and selecting the Close option. Any ECOs marked for deletion will be removed from the database.

Viewing ECO Assumptions

1. Select the View option from under the main ECOs menu bar.
2. Select either Electrical, Envelope, Heating/Cooling, Lighting, Miscellaneous, Renewables, Utilities, or Water, depending on the type of ECO to be viewed.
3. When the Select ECO Assumptions to View popup appears, click on the specific ECO to be viewed.
4. After the desired ECO has been selected, press the F12 key to accept your choice.

Note: Although you may select more than one set of ECO assumptions and rules for viewing, only the first one selected will be displayed.

Printing ECO Assumptions

1. Select the Print option from under the main ECOs menu bar.
2. Select either Electrical, Envelope, Heating/Cooling, Lighting, Miscellaneous, Renewables, Utilities, or Water, depending on the type of ECO to be printed.
3. When the Select ECO Assumptions to Print popup appears, click on the specific ECO to be printed.
4. After the desired ECO has been selected, press the F12 key to accept your choice.

Note: Although the program will allow selection of more than one set of ECO assumptions and rules for printing, only the first one selected will be printed out.

Analyses

Four basic operations can be performed under the Analyses option:

- a simple analysis
- a financial summary analysis
- a resource summary analysis
- a pollution summary analysis.

Note: A simple analysis allows competing technologies to be compared to one another. It does not filter out overlapping technologies (i.e., technologies that are competing for a retrofit). All of the summary analyses, on the other hand, do exclude from the summary all overlapping technologies except the one that is best according to the user-specified criterion chosen (see Modifying the Overlap Criterion, page 60). Thus, a manual summation of the results of a simple analysis will not necessarily equal the results of a financial, resource, or pollution summary analysis.

Performing a Simple Analysis

Three steps are involved in performing a simple analysis:

1. Select an installation for analysis
2. Select an ECO for analysis
3. Perform the simple analysis.

To perform a simple analysis:

1. Select the Perform option from under the main Analyses menu bar.
2. Select the Simple option.
3. While the analysis is being performed, a message will be displayed indicating that the analysis is in progress. When the message disappears, the analysis is complete.
4. View the results of the analysis.

Note: A simple analysis evaluates the effects of each selected ECO at each selected installation. For example, if three family housing heating technologies are selected for evaluation at a single installation, three sets of results will be displayed in the results database. The results of the three technologies can then be ranked and compared to one another.

Performing a Financial Summary Analysis

1. Select the Perform option from under the main Analyses menu bar.
2. Select the Financial Summary option.
3. While the analysis is being performed, a message will be displayed indicating that the analysis is in progress. When the message disappears, the analysis is complete.
4. View the results of the analysis.

This option is appropriate for summarizing the financial data generated from the previously performed simple analysis.

Note: This function will summarize only that information resulting from the previously run simple analysis, so you must first perform a simple analysis before running the financial summary analysis.

Performing a Resource Summary Analysis

1. Select the Perform option from under the main Analyses menu bar.
2. Select the Resource Summary option.
3. While the analysis is being performed, a message will be displayed indicating that the analysis is in progress. When the message disappears, the analysis is complete.
4. View the results of the analysis.

This option is appropriate for summarizing the resource data generated from the previously performed simple analysis.

Note: This function will summarize only that information resulting from the previously run simple analysis, so you must first perform a simple analysis before running the resource summary analysis.

Performing a Pollution Summary Analysis

1. Select the Perform option from under the main Analyses menu bar.
2. Select the Pollution Summary option.
3. While the analysis is being performed, a message will be displayed indicating that the analysis is in progress. When the message disappears, the analysis is complete.
4. View the results of the analysis.

This option is appropriate for summarizing the pollution data generated from the previously performed simple analysis.

Note: This function will summarize only that information resulting from the previously run simple analysis, so you must first perform a simple analysis before running the pollution summary analysis.

Results

Four basic operations can be performed under the Results option:

- write the results of an analysis to a spreadsheet
- order the results of an analysis
- view the results of an analysis numerically
- view the results of an analysis graphically.

Writing the Results of a REEP Analysis to a Spreadsheet

1. Select the Write to Spreadsheet option from under the main Results menu bar.
2. Select either Simple, Financial Summary, Resource Summary, or Pollution Summary.
3. Select 1-2-3, Excel, Multiplan, Symphony, or VisiCalc, depending on the type of spreadsheet you would like to write to.
4. When prompted, type in the name of the spreadsheet you would like the results written to.
5. Press Enter.

The default spreadsheet name provided will be used if you choose not to type in your own spreadsheet name.

Ordering the Results of a REEP Analysis

1. Select the Order option from under the main Results menu bar.
2. Select either Simple, Financial Summary, Resource Summary, or Pollution Summary.
3. After the Order Results window appears, enter into the Order column a 1, 2, 3, 4, 5, 6, 7, 8, or 9, depending on the order in which you would like the results displayed.

4. In the Direction column, indicate the desired direction of each of those sorts

   - A (ascending)
   - D (descending)

For example, to order the results of a simple analysis first by installation and then by filtered simple payback (to see which ECOs payback the quickest at which installations), you would place a 1 in the Order column next to Installation and a 2 in the Order column next to Filtered Simple Payback. Then, if you would like the installations and the filtered simple payback to be organized in ascending order, you would place an A in the Direction column next to both Installation and Filtered Simple Payback.

5. To modify the information in a field, use the arrow keys to highlight the field and then type in the desired value.
6. When finished, close the window by clicking on the button in the upper left corner of the window and selecting the Close option.

Viewing the Results of a REEP Analysis Numerically

1. Select the View Numerically option from under the main Results menu bar.
2. Select either Simple, Financial Summary, Resource Summary, or Pollution Summary.
3. After the View Results Numerically window appears, use the arrow keys or mouse to move about freely in this window.
4. When finished, close the window by clicking on the button in the upper left corner of the window and selecting the Close option.

Note: To see an explanation of how a particular value in the results database was derived, use the arrow keys to highlight the value of interest and press the F2 key. Not only will the rule used to derive the value be displayed, but the values of the variables used in the calculation will also be shown. This option is only available when looking at the numeric results of a simple analysis.

Viewing the Results of a REEP Analysis Graphically

1. Select the View Graphically option from under the main Results menu bar.
2. Select either Simple, Financial Summary, Resource Summary, or Pollution Summary.
3. After the View Results Graphically window appears, enter a Y in the Graphfield column by the field you would like graphed.

4. In the Graphlabel column, enter an E or an I to indicate that you will be graphing ECOs or Installations.
5. When finished, close the window by clicking on the button in the upper left corner of the window and selecting the Close option.
6. A Microsoft Graph window will appear. Carefully follow the on-line instructions provided by Microsoft Graph.

Reports

Two basic operations can be performed under the Reports option:

- view reports
- print reports.

Viewing Reports

1. Select the View option from under the main Reports menu bar.
2. Select either Simple, Financial Summary, Resource Summary, Pollution Summary, or Composite Summary.

   - After selecting Simple, the Select Installation/ECO Report to View popup will appear.
     - click on the Installation/ECO combination to be viewed
     - press the F12 key to accept your choice.

     Note: Although more than one installation/ECO may be selected for viewing, only the first one selected will be displayed.

   - After selecting Financial Summary, Resource Summary, Pollution Summary, or Composite Summary, you will be prompted for the subtitle to appear at the top of the report.
     - type in the subtitle of the report
     - press Enter.

   - After entering the report subtitle, you will be asked if you want to append to the report a listing of the installations and ECOs that were included in the current analysis. Select either Yes or No.

Note: For the results of the service report to be reliable, a simple analysis must be run first on ALL of the installations in the desired service, and then run a financial summary, a resource summary, and a pollution summary.

Printing Reports

1. Select the Print option from under the main Reports menu bar.
2. Select either Simple, Financial Summary, Resource Summary, Pollution Summary, or Composite Summary.

- After selecting Simple, the Select Installation/ECO Report to Print popup will appear.
  - click on the Installation/ECO combination to be printed
  - press the F12 key to accept your choice.

  Note: Although you may select more than one installation/ECO for printing, only the first one selected will be printed out.

- After selecting Financial Summary, Resource Summary, Pollution Summary, or Composite Summary, you will be prompted for the subtitle to appear at the top of the report.
  - type in the subtitle of the report
  - press Enter.

- After entering the report subtitle, you will be asked if you want to append to the report a listing of the installations and ECOs that were included in the current analysis. Click either Yes or No.

Note: For the Financial Summary, Resource Summary, or Pollution Summary to print correctly, you must first select Setup... in the Print dialog box and then select Landscape in the Print Setup dialog box. Next, select OK in the Print Setup dialog box and then OK in the Print dialog box.

Note: For the results of the service report to be reliable, a simple analysis must be run first on ALL of the installations in the desired service, and then run a financial summary, a resource summary, and a pollution summary.

Miscellaneous

Six basic operations can be performed under the Misc option:

- modify the ECIP discount factors
- modify the ECIP filters
- modify the project size factors
- modify the combustion efficiencies
- modify the overlap criterion
- modify the output columns to display.

Modifying ECIP Discount Factors

1. Select the Modify option from under the main Misc menu bar.
2. Select ECIP Discount Factors.
3. When the Modify ECIP Discount Factors window appears, make the modifications to the data you are interested in.
   - use the arrow keys to highlight the field
   - type in the desired value.
4. When finished, close the window by clicking on the button in the upper left corner of the window and selecting the Close option.

Note: The ECIP database table contains the uniform present worth factors and energy discount factors for various fuel types for ECOs with either a 10, 15, or 20 year life span in all five Department of Energy (DOE) regions.

Modifying ECIP Filters

1. Select the Modify option from under the main Misc menu bar
2. Select ECIP Filters.
3. When the Modify ECIP Filters window appears, make the modifications to the filters you are interested in.
   - use the arrow keys to highlight the field
   - type in the desired value.
4. When finished, close the window by clicking on the button in the upper left corner of the window and selecting the Close option.

Note: The two fields in the ECIP Filters database table correspond to ECIP's SIR and simple payback period criteria (i.e., 1.25 and 10 years, respectively).

Modifying Project Size Factors

1. Select the Modify option from under the main Misc menu bar.
2. Select Project Size Factors.
3. When the Modify Project Size Factors window appears, make any modifications to the table.
   - use the arrow keys to highlight the field
   - type in the desired value.
4. When finished, close the window by clicking on the button in the upper left corner of the window and selecting the Close option.

Modifying Combustion Efficiencies

1. Select the Modify option from under the main Misc menu bar.
2. Select Combustion Efficiencies.
3. When the Modify Combustion Efficiencies window appears, make any modifications to the table.
   - use the arrow keys to highlight the field
   - type in the desired value.
4. When finished, close the window by clicking on the button in the upper left corner of the window and selecting the Close option.

Modifying Overlap Criterion

1. Select the Modify option from under the main Misc menu bar.
2. Select Overlap Criterion.
3. When the Modify Overlap Criterion window appears, place a Y in the Criterion column next to the field to be used as the overlap criterion. Be sure that only one Y is in the Criterion column; all other designators should be N. The criterion you choose will be used by REEP to keep overlapping technologies from being included in any subsequent financial, resource, or pollution summaries that may be run.
4. To modify a value in the Criterion column, use the arrow keys to highlight the field and type in the desired value.
5. When finished, close the window by clicking on the button in the upper left corner of the window and selecting the Close option.

Modifying Output Columns to Display

1. Select the Modify option from under the main Misc menu bar.
2. Select Output Columns to Display.

3. When the Modify Output Columns to Display window appears, place a Y in the Outcols column next to the field names to be seen when viewing the results of the REEP analysis. You may display as many of these fields as you want.
4. To modify a value in the Outcols column
   - use the arrow keys to highlight the field
   - type in the desired value.
5. When finished, close the window by clicking on the button in the upper left corner of the window and selecting the Close option.

Note: The number of output columns you wish to have displayed on the computer's screen does not affect the number of columns written when saving to an Excel spreadsheet. That is, all of the columns are written to the spreadsheet regardless of how many columns are displayed on the screen.

Quit

Under the Quit option, you may quit the REEP system. To quit REEP, select the Quit REEP option from under the main Quit menu bar.

Help

The two Context Sensitive Help (CSH) functions and the Explanation Facility (EF) function are very useful and important to be aware of.

1. The first CSH function provides you with context sensitive instructions on how to perform any REEP task. To use this function, press the F1 key.
2. The second CSH function provides additional information on any field in any database. To use this function, press the F3 key when viewing any open database. This function provides you with a full description of the column name, its units, and the source document where the value can be found or explained.
3. The EF function can be evoked only when viewing the numeric results of a REEP simple analysis. This function is invoked by pressing the F2 key and provides you with an explanation of how any value in the results of a REEP analysis was derived. Not only will the rule used in the calculation be displayed, but the values of the variables used in the calculation will also be shown.

Three basic operations can be performed under the Help option:

- browse through the contents of the REEP Help system

- perform a search on the contents of the REEP Help system
- find development information about the current version of the REEP system.

At any time during a REEP session, you may access context-sensitive help on the function you are trying to perform. For example, if trying to select an installation for analysis and unsure about what to do next, press the F1 key. Step-by-step instructions on how to properly select an installation for analysis will be given.

Contents

To browse through the contents of the REEP Help system, select the Contents option from under the main Help menu bar. This option allows you to get help and/or information on any of the major topics in the REEP system.

Search

To search the contents of the REEP Help system, select the Search option from under the main Help menu bar. This option allows you to search the REEP Help system using keywords in order to get help and/or information on any of the major topics in the REEP system.

About REEP

To get development information on the current version of REEP, select the About REEP option from under the main Help menu bar.

5 Performing a REEP Analysis

REEP is a flexible and powerful tool for energy and water conservation opportunity analysis. Rather than one immense program, REEP consists of many smaller files that interact with one another and are largely available to the user for modifications.

Flexibility includes the ability to choose one installation, a major command, or all installations and the choice of ECO/WCO(s). For example, analyzing one installation with all ECO/WCOs allows the individual installation energy manager to evaluate potential ECO/WCOs. Composite, financial, resource, and pollution summaries can be printed within minutes. Simple changes can be made for a more accurate representation of the installation or ECO/WCOs. With changes in the installation data or ECO/WCO assumptions, comparisons can be made quickly.

The analysis of all installations and all ECO/WCO options is a powerful scenario that allows upper level management to investigate potential savings for the whole service or services. Within minutes, all summaries can be prepared for analysis.

The power of the REEP model is in its flexibility. The database containing all the installation characteristics can be modified by the user as desired, as can each individual ECO assumption file. Furthermore, "filter" values that sort out acceptable results and selection criteria for competing technologies are also accessible for modification. This capability to access various files and allow changes permits the analyst to use the program in a number of ways.

Analysis Scenarios

Following is a partial list of hypothetical situations that could be analyzed using the REEP program:

1. Develop a "first-cut" list of ECOs for an installation. This task could be as easy as using the program as-is to perform a Simple Analysis and then running Summary Reports. The results would point to which ECOs are most likely to meet Federal economic criteria and should be analyzed in greater detail.

2. Use the results from the "first-cut" analysis to prioritize engineering studies (i.e., study those ECOs that demonstrate the greatest potential based on whatever criteria the analyst has determined to be of greatest importance.)
3. Perform a parametric-type analysis on individual ECOs. The analyst may be interested in varying individual parameters of an ECO to determine their effect on the results. The analyst may determine that certain parameters have much greater influence on results than others.
4. Similar to the parametric-type analysis, individual ECO assumption variables may be studied to determine their sensitivity to change (i.e., change in output magnitude to change of input that causes it). For example, it may be desirable to vary an ECO's cost from one run to another to determine at what point it does or does not become economical.
5. Perform "what-if" scenarios. The analyst may be curious about the implications of increased utility rates. For example, if it is known that electrical demand rates are going to increase, the installation utility rates could be modified and the model rerun. The ramifications of increased demand rates may alter energy conservation strategies and change which ECOs should be studied in greater detail.
6. Analyze effects of DSM rebates/incentives. If users know what type of programs their serving utility is offering, they can adjust the cost of an ECO and rerun the analysis to see what financial and payback implications rebates/incentives have on an ECO.

Although REEP allows ample flexibility and ease of operation, it is important to remember that the model is basically a preliminary analysis tool. More rigorous engineering studies need to be performed after the REEP analysis. Generally, *final* conclusions for energy savings projects should not be based on REEP results. However, some of the ECOs are not difficult to model analytically, and REEP results may be quite accurate. For example, the relamping of an exit light is simple to model and analyze versus the modeling of an ice storage system. The confidence level of the results of simple ECOs is greater than those relying on numerous broad assumptions.

Analysis Results

REEP results can be examined in a number of ways. Flexibility in representing the results provides analysts the capability to examine them from different vantage points according to their own needs. One analyst may be interested in listing ECOs that demonstrate the most rapid paybacks, while another may be interested in ECOs that maximize pollution reduction.

The results can be sorted and ranked based on those of particular interest to the user. For example, the ECOs could be sorted by installation and ranked in ascending order by payback. The user can focus on results of interest and quickly rank them in a more useful order. The user can also modify the results display and select which values are to be shown.

REEP Results File

The entire results file can be written to a spreadsheet or viewed directly on the screen. Writing the results to a spreadsheet file is useful for manipulating the values with typical spreadsheet abilities. When viewed on the screen, each result can be queried for the algorithms that produced that result. This capability allows the user to investigate the results and better understand their origins or question their validity. However, the results file is quite large and can be cumbersome. For this reason, the results may be reviewed by several more flexible, concise, and useful methods discussed below.

Graphing Utility

Several types of graphs are available through the REEP graphing utility, including pie-charts, bar graphs, and three-dimensional axes. A particularly useful graphing approach is to sort the results based on a value of interest and then graph the sorted results to see trends between installations, ECOs, etc. Some useful results to sort and graph are initial cost, savings per year, simple payback, savings to investment ratio, total energy savings, electric savings, demand savings, gas savings, and investment by installation. Figure 2 is a graph of simple paybacks for lighting Army-wide.

Reports Utility

The REEP reports utility manipulates and summarizes results into four concisely formatted reports: financial, resource, pollution, and composite. The reports sum up or average the results across all selected installations for each ECO. The financial, resource, and pollution reports summarize the results of their respective areas. The composite report provides totals across all selected installations and all selected ECOs. Also displayed are percent resource and financial savings and percent pollution reduction for all selected installations and ECOs. Another useful feature in the REEP reports utility is the energy target summary. This summary shows the estimated resource reductions for 1985 through 1993 and 1985 through 2005 and can be useful for planning energy reduction goals. Appendix E shows the composite summary and the financial, resource, and pollution savings reports generated as a result of selecting all Army installations and all ECO/WCOs.

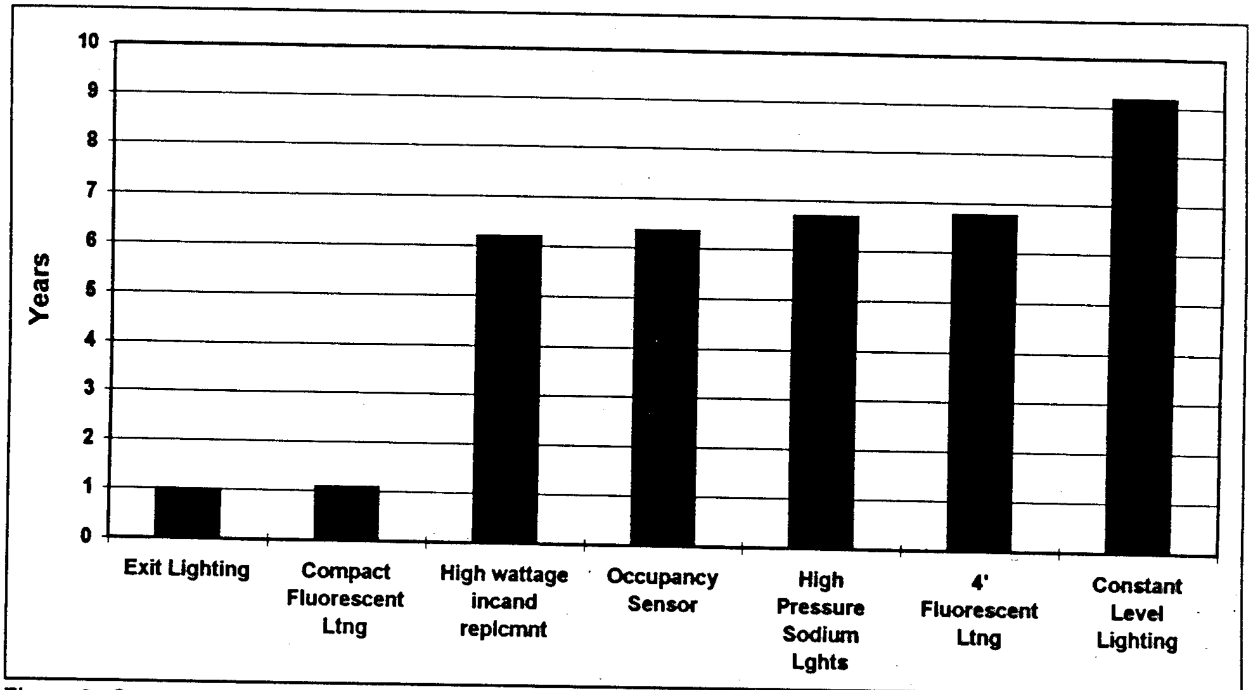


Figure 2. Sample REEP graph showing simple paybacks for Army lighting.

6 Conclusions and Recommendations

Conclusions

Under development for approximately 2 years, the REEP program has become a versatile and user-friendly program that can be used to estimate the energy and water savings potential for various technologies across domestic DOD installations. Before the inception of the REEP program, the capability to assess conservation opportunities across DOD was unavailable.

The REEP program can be used in many different ways by a variety of people. Upper level DOD management can use the program to assess "big-picture" issues regarding conservation potential, associated costs, and paybacks across DOD. Lower level management, such as installation energy managers, can use the program as an initial high-level screening tool to help focus detailed study efforts or for other tasks that may need to be accomplished.

The overall results from the REEP program indicate that opportunities exist for substantial energy and water conservation across the 239 military installations in the REEP database. Results show that compliance with Federal energy and water savings mandates is possible, but only with substantial investment. Results clearly indicate that to save money it will cost money. Compliance with Federal mandates will only be possible if conservation efforts are adequately funded. Conservation efforts range from properly funding O&M for buildings and infrastructure to installation of new energy efficient technologies.

REEP calculated costs for conservation can be used as justification for the establishment of substantial funding streams targeted for conservation efforts in order to comply with Federal mandates.

Recommendations

The REEP program has filled a vacuum in the hierarchy of energy analysis tools. This is the first attempt at creating a comprehensive high-level energy analysis type tool. As with most other first-generation developments, the REEP program can be improved

and refined. The program was not intended to replace or compete with other analysis tools, but rather to fill a void that existed at the upper level of energy analysis tools. For this tool to remain current, a minimum amount of yearly funding should be allocated to maintain the databases within the program. Preferable to the minimum funding, funding for further program enhancement and development should be allocated.

Metric conversion factors.

1 sq ft	=	0.093 m^2
1 cu ft	=	0.028 m^3
1 gal	=	3.78 L
°F	=	(°C × 1.8) + 32

References

Architectural and Engineering Instructions (AEI) Design Criteria (Headquarters, U.S. Army Corps of Engineers [HQUSACE], 9 December 1991).

Army Regulation [AR] 415-17, *Construction Cost Estimating for Military Programming* (Headquarters, Department of the Army [HQDA], Washington, DC, 15 March 1980).

Block, D.L., "Solar Water Heating: The Making of a Simple Standard Appliance, Innovative Energy & Environmental Applications," *Proceedings of the 15th World Energy Engineering Congress* (27 October 1992).

Buonicore, Anthony J., and Wayne T. Davis, ed., *Air Pollution Engineering Manual* (Van Nostrand Reinhold, 1992).

Center for Study of Responsive Law, *Energy Ideas*, Vol. 1, No. 6 (December 1992).

Center for Study of Responsive Law, *Energy Ideas — Water Technology*, Vol 1, No. 3 (September 1992).

Chandler, Howard M., ed., *Means Repair and Remodeling Cost Data, 14th Annual Edition* (R.S. Means Company Inc, 1992).

Code of Federal Regulations (CFR), title 40, chapter 1, subpart D, part 60, section 40.

Consumer Energy Council of America Research Foundation, *Incorporating Environmental Externalities into Utility Planning: Seeking a Cost-Effective Means of Assuring Environmental Quality* (Consumer Energy Council of America, July 1993).

Department of the Army Technical Manual (TM), *Engineering Weather Data*, TM 5-785 (Department of the Army, Washington, DC, 1 July 1978).

Energy Information Administration (EIA), *Cost and Quality of Fuels for Electric Utility Plants 1992*, report DOE/EIA-0191 (92) (Government Printing Office, August 1993a).

EIA, *Household Energy Consumption and Expenditures 1987*, DOE/EIA-0321/1(87) (Government Printing Office, 1987).

EIA, *Electric Power Monthly*, report DOE/EIA-0226(94/06) (Government Printing Office, June 1994).

EIA, *Electric Power Monthly*, report DOE/EIA-0226(94/02) (Government Printing Office, February 1994).

Federal Register (FR), vol. 59, no. 47, pp 11463-11471.

Griggs, E.I., T.R. Sharp, and J.M. MacDonald, *Guide for Estimating Differences in Building Heating and Cooling Energy Due to Changes in Solar Reflectance of a Low-Sloped Roof*, Report ORNL-6527 (Oak Ridge National Laboratory, August 1989).

Hollick, John, and Earl Aslin, *Conserval SOLARWALL Air Heating System Design Manual* (Conserval Engineering, Inc., 1990).

Hollick, John, *Air Heating System Design Manual* (Conserval Engineering, Inc., 1990).

Huang, Y.J., H. Akbari, and H. Taha, *The Wind-Shielding and Shading Effects of Trees on Residential Heating and Cooling Requirements*, Report LBL--24131, DE90 011595 (Lawrence Berkley Laboratory, January 1990).

Kiley, Martin D., and William M. Moselle, ed., *1991 National Construction Estimator* (Craftsman 1990).

Maloney, S.W., R. J. Scholze, and J.T. Bandy, *Preventing Water Loss in Water Distribution Systems: Money-Saving Leak Detection Programs*, Technical Report (TR) N-86/05/ADA167556 (U.S. Army Construction Engineering Research Laboratory [USACERL], March 1986).

McPherson, E. Gregory, "Evaluating the Cost Effectiveness of Shade Trees for Demand-Side Management," *The Electricity Journal*, Vol. 6 No. 9 (November 1993).

Means Residential Cost Data 1993, 12th Edition (R.S. Means Company, Inc., 1993).

Meier, Alan, "Is That Old Refrigerator Worth Saving?" *Home Energy*, Vol. 10, No. 1 (January/February 1993).

Military Handbook (Mil-Hdbk 1003/19), *Design Procedures for Passive Solar Buildings* (Department of Defense, Washington, DC, 3 May 1987).

Ottinger, Richard L., David R. Wooley, Nicholas A. Robinson, David R. Hodas and Susan E. Babb, *Environmental Costs of Electricity* (Oceana Publications, Inc., 1990).

Pan Am World Services, Inc., *Heat Distribution Systems Life Cycle Cost Analysis - Comparison Between Direct Buried and Shallow Trench Systems*, Report 130319 (Pan Am World Services, Inc., June 1985).

Parsons, Robert A., ed., *1989 ASHRAE Handbook of Fundamentals* (American Society of Heating, Refrigerating and Air-conditioning Engineers, Inc., 1989).

Petersen, Stephen R., *Energy Prices and Discount Factors for Life-Cycle Cost Analysis 1994*, (Department of Commerce, Technology Administration National Institute of Standards and Technology, October 1993).

Potts, Noel, *User Guide for High-Efficiency Heating System Conversion*, User Guide, FEAP-UG-92/04 (USACERL, January 1992).

Public Law (PL) 100-12 S.83 (17 March 1987).

Rea, M.S., ed., *Lighting Handbook*, 8th ed. (Illumination Engineering Society of North America, New York, 1993).

Rundquist, Robert A., "Guide to Simplified Lighting/HVAC Interaction Calculations" (R.A. Rundquist Associates, undated).

Savoie, Martin J., and Jill E. Davidson, "Central Heating Plant Particulate Emission Reduction Through Operation and Maintenance," Air and Waste Management Association Annual Meeting and Exhibition (Air and Waste Management Association, June 1991).

Sliwinski, B.J., et al., *Fixed Facilities Energy Consumption Investigation - Data Analysis*, Interim Report E-143/ADA066513 (USACERL), February 1979).

Sohn, Chang W., and Gerald L. Cler, *Market Potential of Storage Cooling Systems in the Army*, TR E-89/13/ADA213977 (USACERL, September 1989).

Taylor, William, and M.A. Dubravec, *Evaluation of Electrical Energy Consumption and Reduction Potential at the 7th Army Training Command (ATC), U.S. Army, Europe*, TR E-90/07/ADA223569 (USACERL, May 1990).

U.S. Environmental Protection Agency (USEPA), *Supplement D to Air Pollutant Emission Factors,* Report No. AP-42 (USEPA, September 1991).

USEPA, Package of Pollution Prevention Information, 4100(3/94) (USEPA, March 1994).

U.S. Army Engineering and Housing Support Center (USAEHSC), *Facilities Engineering and Housing Annual Summary of Operations, Volume III - Installations Performance, Fiscal Year 1993* (Office of the Assistant Chief of Engineers, USAEHSC, 1993).

Appendix A: Real Property/Infrastructure Information

Army Real Property Data

All data for the Army relating to population, building areas, length of steam and hot water distribution, and number of exterior street lights were obtained from the 1993 *Facilities Engineering and Housing Annual Summary of Operations, Volume III* (U.S. Army Engineering and Housing Support Center 1993, commonly known as the Red Book).

The building areas are supplied both as an installation total and as broken down into the following 10 building types: training; maintenance and production; research, development, and testing; storage; hospital and medical; administration; unaccompanied personnel housing; community facilities; family housing; and miscellaneous other areas.

Army Boiler Capacities

Facility heating plant capacities were obtained from the 1993 Redbook. The boiler and heating plants are divided into three categories:

1. Boiler and heating plants over 3.5 MBtu capacity were treated as central plants serving more than one building.
2. Heating plants from 0.75 MBtu to 3.5 MBtu were assumed to serve large buildings.
3. Heating plants smaller than 0.75 MBtu were considered to serve small to intermediately sized buildings.

Each of these three categories is then further subdivided into the different fuel types: gas, oil, and coal.

Army Chiller Capacities

Facility chiller capacities were obtained from the 1992 Redbook. The air-conditioning equipment is also divided into three categories:

1. Over 100 tons was assumed to be a central facility serving more than one building.
2. Five to 100 tons was considered to serve large facilities.
3. Under 5 tons was considered primarily residential in character.

Air Force Real Property Data

Information for the Air Force building areas was obtained from the Real Property Database (RPDB) maintained by the Air Force. These tapes were obtained from Fred Beason, HQ AFCESA/ENM at Tyndall AFB, FL. These databases contained information on every building on each installation and had to be condensed into the same categories as found in the 1992 Redbook for the Army. Queries were developed that summarized the databases into the same building categories as in the Army. Once completed, the Air Force data were then loaded into the REEP Instdata database.

Information about the population, length of steam and hot water distribution, and number of exterior street lights was not found in the RPDB. This data was requested as part of a infrastructure/utility information questionnaire that was sent to each installation. Following is a summary of the questions submitted to each installation.

1. Estimated population of the base

ELECTRIC UTILITY INFORMATION

2. A copy of the electric bill for January 1993
3. A copy of the electric bill for August 1993
4. If not included, please write the kW peak demand for the last 12 months
5. Estimated number of exterior lights on the base (street and parking lot lights)

WATER UTILITY INFORMATION

6. Amount of water used for the year (thousands of gallons)
7. The unit cost of water supply (if on base, chemical, power, and labor)
8. The unit cost of sewage treatment (if on base, chemical, power, and labor)
9. The estimated length of the water distribution system (miles).

Of the 70 questionnaires sent out, 46 responses were received. The responses varied from being very detailed to only partial responses to the questionnaire. Table A1 summarizes the information received from each installation. Blanks indicate no response.

Table A1. Responses to infrastructure/utility information questionnaire.

	Installation	MAJCOM	Electric Bill Jan-93	Electric Bill Aug-93	kW Peak for year	Total Water	Unit Cost Water	Unit Cost Sewer	Length of Water Dist	No. of Lights
1	BARKSDALE AFB SHREVEPORT LA/MFH	ACC	X	X	X	X	X	X	X	X
2	BEALE AFB MARYSVILLE CA/MFH	ACC	X	X	X	X	X	X	X	X
3	CANON AFB CLOVIS NM/MFH	ACC								
4	DAVIS MONTHAN AFB TUSCON AZ/MFH	ACC	X	X	X	X	X	X	X	X
5	DYESS AFB ABILENE TX/MFH	ACC	X	X	X	X	X	X	X	X
6	ELLSWORTH AFB RAPID CITY SD/MFH	ACC								
7	FAIRCHILD AFB SPOKANE WA/MFH	ACC			X	X	X	X	X	
8	GRAND FORKS AFB EMERADO ND/MFH	ACC	X	X	X	X	X	X	X	X
9	HOLLOMAN AFB ALAMOGORDO NM/MFH	ACC	X	X	X	X	X	X		
10	KEESLER AFB BILOXI MS/MFH	ACC	X	X	X					
11	K. I. SAWYER AFB GWINN MI/MFH	ACC	X	X	X					X
12	LANGLEY AFB HAMPTON VA/MFH	ACC	X	X	X	X	X	X	X	X
13	LUKE AFB GLENDALE AZ/MFH	ACC	X	X	X					
14	MCCONNELL AFB WICHITA KS/MFH	ACC	X	X	X	X	X	X	X	X
15	MINOT AFB ND/MFH	ACC	X	X	X	X	X		X	X
16	MOODY AFB VALDOSTA GA/MFH	ACC	X	X	X	X	X	X	X	X
17	MOUNTAIN HOME AFB ID/MFH	ACC			X	X	X			

	Installation	MAJCOM	Electric Bill Jan-93	Electric Bill Aug-93	kW Peak for year	Total Water	Unit Cost Water	Unit Cost Sewer	Length of Water Dist	No. of Lights
18	NELLIS AFB LAS VEGAS NV/MFH	ACC	X	X		X	X	X	X	X
19	OFFUTT AFB OMAHA NE/MFH	ACC	X	X		X	X	X	X	X
20	POPE AFB FAYETTEVILLE NC/MFH	ACC	X	X		X	X			
21	SEYMOUR JOHNSN AFB GOLDSBR NC/MFH	ACC								
22	SHAW AFB SUMTER SC/MFH	ACC								
23	TYNDALL AFB PANAMA CITY FL/MFH	ACC	X	X	X	X	X	X	X	X
24	WARREN AFB CHEYENNE WY/MFH	ACC	X	X		X	X	X	X	X
25	ARNOLD AFS TULLAHOMA TN/MFH	AFMC								
26	BROOKS AFB SAN ANTONIO TX/MFH	AFMC								
27	EDWARDS AFB CA/MFH	AFMC								
28	EGLIN AFB VALPARISO FL/MFH	AFMC			X	X	X	X	X	X
29	GRIFFISS AFB ROME NY/MFH	AFMC								
30	HANSCOM FIELD MA/MFH	AFMC								
31	HILL AFB OGDEN UT/MFH	AFMC	X	X	X	X	X	X	X	
32	KELLY AFB SAN ANTONIO TX/MFH	AFMC	X	X		X	X	X	X	X
33	KIRTLAND AFB ALBUQUERQUE NM/MFH	AFMC								
34	LOS ANGELES AFS CA/MFH	AFMC	X	X	X	X	X	X	X	X
35	MCCLELLAN AFB SACRAMENTO CA/MFH	AFMC	X	X	X	X	X	X	X	X
36	NEWARK AFS OH	AFMC	X	X		X	X	X	X	X
37	ROBINS AFB GA/MFH	AFMC	X	X	X	X	X	X	X	X
38	TINKER AFB OKLAHOMA CITY OK/MFH	AFMC	X	X	X	X	X	X	X	X

	Installation	MAJCOM	Electric Bill Jan-93	Electric Bill Aug-93	kW Peak for year	Total Water	Unit Cost Water	Unit Cost Sewer	Length of Water Dist	No. of Lights
39	WRIGHT-PAT AFB FAIRBORN OH/MFH	AFMC								
40	ALTUS AFB OK/MFH	AMC	X	X	X	X	X	X	X	X
41	ANDREWS AFB MD/MFH	AMC								
42	CHARLESTON AFB SC/MFH	AMC	X	X	X	X	X	X	X	X
43	DOVER AFB DE/MFH	AMC	X	X	X	X	X	X	X	X
44	HURLBURT FIELD FL/MFH	AMC								
45	LITTLE ROCK AFB AR/MFH	AMC	X	X	X	X	X	X	X	X
46	MALMSTROM AFB GREAT FALLS MT/MFH	AMC								
47	MARCH AFB RIVERSIDE CA/MFH	AMC								
48	MCCHORD AFB TACOMA WA/MFH	AMC	X	X	X	X	X	X	X	X
49	MCGUIRE AFB WRIGHTSTOWN NJ/MFH	AMC	X	X	X	X	X	X	X	X
50	PLATTSBURGH AFB NY/MFH	AMC	X	X	X	X	X	X	X	X
51	SCOTT AFB BELLVILLE IL/MFH	AMC	X	X	X	X	X	X	X	X
52	TRAVIS AFB FAIRFIELD CA/MFH	AMC								
53	COLUMBUS AFB MS/MFH	ATC								
54	GOODFELLOW AFB SAN ANGELO TX/MFH	ATC	X	X	X	X	X	X	X	X
55	LACKLAND AFB SAN ANTONIO TX/MFH	ATC	X	X	X					X
56	LAUGHLIN AFB DEL RIO TX/MFH	ATC	X	X	X	X	X	X	X	X
57	RANDOLPH AFB UNIVERSAL CITY TX/MFH	ATC								
58	REESE AFB HURLWOOD TX/MFH	ATC	X	X	X	X	X	X	X	X
59	SHEPPARD AFB WICHITA FALLS TX/MFH	ATC	X	X		X	X	X	X	X

	Installation	MAJCOM	Electric Bill Jan-93	Electric Bill Aug-93	kW Peak for year	Total Water	Unit Cost Water	Unit Cost Sewer	Length of Water Dist	No. of Lights
60	VANCE AFB ENID OK/MFH	ATC	X	X	X	X	X	X	X	X
61	AF ACADEMY COLO SPRINGS CO/MFH	ACADEMY	X	X	X	X	X	X	X	X
62	BOLLING AFB WASHINGTON DC/MFH	AFDW								
63	GUNTER AFB AL	AU	X	X	X	X			X	X
64	MAXWELL AFB MONTGOMERY AL/MFH	AU	X	X	X	X			X	X
65	FALCON AFB COLORADO	SPACECOM								
66	ONIZUKA AFS CA	SPACECOM								
67	PATRICK AFB COCOA BEACH FL/MFH	SPACECOM								
68	PETERSON AFB COLO SPRINGS CO/MFH	SPACECOM	X	X	X	X	X	X	X	X
69	VANDENBERG AFB LOMPOX CA/MFH	SPACECOM								

Air Force Boiler Capacities and Consumptions

Facility heating capacities for the Air Force installations were obtained from the RPDB. Capacities were extracted from the RPDB and sorted under the capacities used in the REEP model. These assumptions include that the boiler and heating plants over 3.5 MBtu capacity were central plants serving more than one building, the 0.75 MBtu to 3.5 MBtu were heating plants serving large buildings, and heating plants smaller than 0.75 MBtu were serving small to intermediate sized buildings. These three sizes were then broken down into gas, oil, and coal capacities and consumptions.

The RPDB did not provide a breakdown of the boilers and heating plant capacities into the different fuels and their associated consumptions, as did the 1992 Redbook for the Army. The following algorithms incorporating the size and capacity data from the RPDB and the general fuel consumptions obtained from the Defense Energy Information System (DEIS) were used to generate the separate fuel capacities and consumptions for each size group.

It was assumed that coal boilers and heating plants only occurred in the greater than 3.5 MBtu category. The efficiencies of 0.7, 0.65, and 0.6 were applied to gas, oil, and coal respectively. Building Consumption refers to the consumption of the entire installation except Family Housing. Family Housing Consumption was assumed only to affect the overall consumption in the less than 0.75 MBtu category, where it was added to the Building Consumption.

3.5 GCP = (3.5 TC x (0.7 x BGC)) / ((0.7 x BGC) + (0.65 x BOC) + (0.6 x BCC))

3.5 OCP = (3.5 TC x (0.65 x BOC)) / ((0.7 x BGC) + (0.65 x BOC) + (0.6 x BCC))

3.5 CCP = (3.5 TC x (0.6 x BCC)) / ((0.7 x BGC) + (0.65 x BOC) + (0.6 x BCC))

0.75-3.5 GCP = (0.75-3.5 TC x (0.7 x BGC)) / ((0.7 x BGC) + (0.65 x BOC))

0.75-3.5 OCP = (0.75-3.5 TC x (0.6 x BOC)) / ((0.7 x BGC) + (0.65 x BOC))

0.75-3.5 CCP = Assumed to be 0

0.75 GCP = (0.75 TC x (0.7 x BGC)) / ((0.7 x BGC) + (0.65 x BOC))

0.75 OCP = (0.75 TC x (0.65 x BOC)) / ((0.7 x BGC) + (0.65 x BOC))

0.75 CCP = Assumed to be 0

These calculated capacities were then used to prorate actual consumptions for each capacity range.

3.5 GCN = (3.5 GCP x BGC) / (3.5 GCP + 0.75-3.5 GCP + 0.75 GCP)

3.5 OCN = (3.5 OCP x BOC) / (3.5 OCP + 0.75-3.5 OCP + 0.75 OCP)

3.5 CCN = (3.5 CCP x BCC) / (3.5 CCP + 0.75-3.5 CCP + 0.75 CCP)

0.75-3.5 GCN = (0.75-3.5 GCP x BGC) / (3.5 GCP + 0.75-3.5 GCP + 0.75 GCP)

0.75-3.5 OCN = (0.75-3.5 OCP x BOC) / (3.5 OCP + 0.75-3.5 OCP + 0.75 OCP)

0.75-3.5 CCN = Assumed to be 0

0.75 GCN = ((0.75 GCP x BGC) / (3.5 GCP + 0.75-3.5 GCP + 0.75 GCP)) + FHGC

0.75 OCN = ((0.75 OCP x BOC) / (3.5 OCP + 0.75-3.5 OCP + 0.75 OCP)) + FHOC

0.75 CCN	=	Assumed to be 0

where:

TC	=	Total Capacity
GCP	=	Gas Capacity
OCP	=	Oil Capacity
CCP	=	Coal Capacity
GCN	=	Gas Consumption
OCN	=	Oil Consumption
CCN	=	Coal Consumption
BGC	=	Building Gas Consumption
BOC	=	Building Oil Consumption
BCC	=	Building Coal Consumption
FHGC	=	Family Housing Gas Consumption
FHOC	=	Family Housing Oil Consumption

The generated boiler capacities and consumptions were then entered into the REEP model.

Air Force Chiller Capacities

Facility cooling capacities for the Air Force installations were obtained from the RPDB. Capacities were extracted from the RPDB and sorted under the capacities used in the REEP model. The model assumes that over 100 tons is a central facility serving more than one building, 5 to 100 tons serves large facilities, and under 5 tons is primarily residential.

Navy Real Property Data

Information for the Navy pertaining to building areas was obtained from the RPDB maintained by the Navy. The Navy facilities were categorized by "Activities," which were subsets of what USACERL researchers would consider to be installations. Therefore, Activity locations had to be identified first, and then these Activities were joined into what were then referred to as installations. The queries summarized the Activities and then combined all Activities that related to an installation. From one to 54 Activities made up an installation. Once completed, the Navy data were loaded into the REEP Instdata database.

The Navy RPDB also contained some other infrastructure data required for the REEP installation database. For example, the RPDB had some information about the length of the steam and hot water distribution lines, which was put into the REEP model but was not complete.

Navy Boiler Capacities and Consumptions

The RPDB maintained by the Navy did not provide boiler capacities or consumptions for its activities, as did the 1992 Redbook for the Army. Estimations of boiler capacities and consumptions for the Navy were made based on observations of available Army data. It was assumed that U.S. Army Forces Command (FORSCOM) provided the most typical situations that could be applied to the rest of DOD. A series of regressions were run to determine which factors most influence an installation's boiler capacities. The results indicated that the total area, heating degree days (HDD), total gas consumption, the length of steam and hot water distribution systems, and the winter design temperature had the largest effect. These factors for the Army installations were then regressed against their known respective boiler capacities. Table A2 shows the fits of the regressions.

Table A2. Navy boiler capacities and regressions.

Gas Boilers			
Regression Statistics	Sm Gas Boilers	Med Gas Boilers	Lrg Gas Boilers
Multiple R	0.576777681	0.587420148	0.889031846
R Square	0.332672493	0.345062431	0.790377624
Adjusted R Square	0.165840616	0.181328038	0.73797203
Standard Error	319.7152576	292.9985556	129.5519813
Observations	26	26	26
	Coefficients	Coefficients	Coefficients
Intercept	211.2600241	366.5602591	150.4770726
total area	0.027288496	0.026707938	0.008586245
hdd	-0.015083735	-0.065581375	-0.033218652
gascon	7.43312E-05	-1.40659E-05	0.000462794
shwpip	-1.680329654	-1.363467711	-1.282134432
windestem	-4.543871837	-7.237446001	-3.345762449

Oil Boilers			
Regression Statistics	Sm Oil Boilers	Med Oil Boilers	Lrg Oil Boilers
Multiple R	0.466643137	0.589029264	0.621152795
R Square	0.217755818	0.346955474	0.385830795
Adjusted R Square	0.022194772	0.183694342	0.232288494
Standard Error	259.6135961	166.0434573	491.7312148
Observations	26	26	26
	Coefficients	Coefficients	Coefficients
Intercept	862.1022371	179.6919973	636.417692
total area	-0.005599009	0.000995943	0.002474353
hdd	-0.12189705	-0.036536098	-0.130869827
oilcon	0.000526258	0.000166276	0.000669952
shwpip	0.131084991	0.913577543	2.688862292
windestem	-12.72631265	-3.238657669	-11.0047983
Coal Boilers			
Regression Statistics	Sm Coal Boilers	Med Coal Boilers	Lrg Coal Boilers
Multiple R	0.953658373	0.999044135	0.998250313
R Square	0.909464293	0.998089184	0.996503687
Adjusted R Square	0.886830366	0.99761148	0.995629608
Standard Error	12.60765023	1.579873188	1.010527381
Observations	26	26	26
	Coefficients	Coefficients	Coefficients
Intercept	-8.752310325	-0.342146653	0.131591704
AREATOT	-4.48322E-05	7.25681E-06	5.81081E-06
hdd	0.002958154	-9.4165E-06	-0.000115778
coalcon	0.000715505	0.000696765	0.000330944
shwpip	0.013175413	0.003340784	0.00141301
windestem	0.006422196	-0.001602908	-0.001153606

These regressions established coefficients for each of the factors, which were then used to form algorithms used to predict boiler capacities at each Navy installation in the format required for the REEP model. These assumptions include that the boiler and heating plants over 3.5 MBtu capacity were central plants serving more than one building, the 0.75 MBtu to 3.5 MBtu heating plants were serving large buildings, and heating plants smaller than 0.75 MBtu were serving small to intermediate sized buildings. The three sizes are then broken down into gas, oil, and coal capacities and consumptions. "If" statements were used to zero out the capacities where no consumption was occurring and to zero out any negative figures.

Once the Navy's boiler capacities were established, the same formulas used to calculate the boiler consumptions for the Air Force were applied to the Navy. The end results were then entered into the REEP model.

Navy Chiller Capacities

The RPDB for the Navy does not include chiller capacities for its activities. Estimates of chiller capacities to fit the model's format were made from observations of the RPDB maintained by the Air Force. The model assumes that over 100 tons is a central facility serving more than one building, 5 to 100 tons serves large facilities, and under 5 tons is primarily residential. An average ton per square foot for each building type was established from the Air Force data. This average was then applied to each building type along with a weighting factor that distributes the capacity among the model's three capacity ranges for each building type. These figures were then summed up to arrive at the total chiller capacity for each installation. Table A3 lists the ton per square foot averages and weighting factors for each building type.

Table A3. Chiller capacity for Navy building types.

Building Type	Ton per Sq Ft	Large (>100)	Med (5-100)	Small (<5)
Barracks	0.0031	0.67	0.33	0
Admin	0.0028	0.5	0.45	0.05
Hosp	0.0028	0.75	0.25	-
R&D	0.0032	0.5	0.5	-
Trng	0.0021	0.125	0.7	0.1
Fam Hsg	0.0017	-	-	1
Community	0.0029	-	0.9	0.1
Storage	-	-	-	-
Maint	0.0004	-	0.5	0.3
Other	-	-	-	-

Appendix B: Utility Information

Electrical

Numerous values pertaining to each installation's electrical usage are used in the REEP model. The annual peak demand (kW), marginal energy rate ($/kWh), marginal summer and winter demand rates ($/kW-month), and ratchet percentages were obtained from the installation bills, Electric Rate Book, or estimates.

The marginal energy rate was adjusted to a 1994 rate by Department of Energy regional escalation rates for 1994. Escalation rates were used because insufficient data were available after 1993. Energy rates prior to 1992 were adjusted to 1992 with average state rate increases and then escalated appropriately. Finally, the adjusted rate was converted from $/kWh to $/MBtu.

The demand rates were used to compute the annualized baseload and summer demand costs ($/kW-year) in a MicroSoft® Excel spreadsheet. The annualized baseload demand cost (BASDEM) is the value of one kW over the course of a year (year long kW reduction), while the annualized summer demand cost (SUMDEM) is the value of one kW during the summer months only, which is applicable to cooling technologies. To provide a conservative rate estimation, no escalation was applied to these demand rates.

The summer season length is considered to be 4 months unless otherwise stated in the rate schedule found in the Electric Rate Book. Note that if the ratchet fell below 50 percent, it was considered negligible and discarded to provide a more conservative rate. Note that both BASDEM and SUMDEM are the same when a high ratchet is present. The formulas used in the spreadsheet follow.

Annualized Baseload Demand Cost (BASDEM):

if the ratchet is below 50 percent

BASDEM ($/kW-year) = [summer demand cost ($/kW-mon) x summer season (mon/yr)]
\+ [winter demand cost ($/kW-mon) x winter season (mon/yr)]

if the ratchet is 50 percent or higher

BASDEM ($/kW-year) = [summer demand cost ($/kW-mon) x summer season (mon/yr)]
+ [winter demand cost ($/kW-mon) x winter season (mon/yr)
× ratchet (%)]

Annualized Summer Demand Cost (SUMDEM):

if the ratchet is below 50 percent

SUMDEM ($/kW-yr) = [summer demand cost ($/kW-mon) × summer season (mon/yr)]

if the ratchet is 50 percent or higher

SUMDEM ($/kW-yr) = [summer demand cost ($/kW-mon) × summer season (mon/yr)]
+ [winter demand cost ($/kW-mon) × winter season (mon/yr)
× ratchet (%)]

Where the utility was unknown or unclear, rates from a local utility were used. Where more than one utility or meter serviced an installation, the rate structure of the prominent utility or meter was used.

Sample Electrical Calculations

A sample calculation for Fort Hood follows:

Basic Electric Utility Information	
Utility	Texas Utilities Electric Company
Rate	General Service-Primary
Year of Rate	1992
Marginal Energy Rate	$0.02481/kWh
Summer Demand Rate	$14.49/kW
Winter Demand Rate	$14.49/kW
Summer Season	4 months
Ratchet Percent	80 %

BASDEM

BASDEM ($/kW-year) = [summer demand cost ($/kW-mon) × summer season (mon/yr)]
+ [winter demand cost ($/kW-mon) x winter season (mon/yr)
× ratchet (%)]

BASDEM ($150.72/kW-yr) = [summer demand cost ($14.49/kW-mon)

BASDEM ($150.72/kW-yr) = [summer demand cost ($14.49/kW-mon)
× summer season (4 mon/yr)]
+ [wint. dem. cost ($14.49/kW-mon)
× wint. seas. (8 mon/yr) x ratch (80%)]

SUMDEM

SUMDEM ($/kW-yr) = [summer demand cost ($/kW-mon) × summer season (mon/yr)]
+ [winter demand cost ($/kW-mon) × winter season (mon/yr)
× ratchet (%)]

SUMDEM ($150.72/kW-yr) = [summer demand cost ($14.49/kW-mon)
× summer season (4 mon/yr)]
+ [wint. dem. cost ($14.49/kW-mon)
× wint. seas. (8 mon/yr) x ratch (80%)]

Adjusted Energy Rate

First convert the energy rate from $/kWh to $/MBtu

$0.02481/kWh *293.08 kWh/1 MBtu = $7.272194/MBtu

Next, adjust to 1994 dollars by using escalation rates.

1994 energy rate ($/Mbtu) = 1992 energy rate ($/MBtu) * 1993 escalation * 1994 escalation

$7.239304/MBtu = $7.272194/MBtu * (0.98919) * (1.006356)

Army Utilities

Electrical rates for Army installations were obtained by first identifying the utility serving the installation, determining what rate schedule it was on, and then pinpointing marginal, demand, and ratchet information in the rate schedule. The Facilities Energy Power and Utilities team at USACERL had conducted a survey prior to the REEP project that contained information regarding which utility served each Army installation, its peak demand, and other miscellaneous utility information. Precise electrical rate information was obtained from the Electric Rate Book once the serving utility and rate schedule were known. These rates were then manipulated as detailed in the Electrical section of this appendix.

Data regarding annual consumption (MBtu) and cost ($/MBtu) for gas, oil, and coal for each Army installation were obtained from the Defense Energy Information System (DEIS).

Army installation water consumption (Kgal), unit cost ($/Kgal), total cost ($), and sewage processed (Kgal), unit cost ($/Kgal), and total cost ($) were all obtained from the 1992 Red Book.

Air Force Utilities

The electrical utility supplier for each Air Force installation was identified through information obtained from the infrastructure/utility questionnaire submitted to each installation. Refer to Appendix B for more on this questionnaire. Once the utility serving the installation and the rate schedule they were on were identified, precise electrical rate information was obtained from the Electric Rate Book. These rates were then manipulated as detailed in the Electric section of this appendix. For installations that did not respond to the questionnaire, USACERL identified the utility serving the area that the installation was in and used a rate schedule for large users.

Data regarding annual consumption (MBtu) and cost ($/MBtu) for gas, oil, and coal for each Air Force installation were obtained from the DEIS.

The annual water and sewer consumption/processing costs, quantities, and rates for each Air Force installation were identified through information obtained from the infrastructure/utility questionnaire submitted to each installation. For installations that did not respond to the questionnaire, USACERL developed algorithms based on known water consumption data to infer water consumption, and an average unit cost per thousand gallons was also determined from known costs.

For installations where the amount of sewage processed was unknown, a regression was run on existing Army data obtained from the 1992 Redbook to find a correlation between water consumption and sewer consumption. Several variations of the data were tried:

- All existing data as found in the Army data in the REEP model
- Sewer consumption normalized to not exceed water consumption (done to minimize the effects of combined sewer systems and ammunition and tank plants)
- Ammunition and tank plants and arsenals taken out (no normalization)
- Ammunition and tank plants and arsenals taken out (with normalization)
- Ammunition and tank plants and zero values taken out (with normalization).

The second variation of data was selected as the most appropriate correlationship to use. The amount of sewage processed for the Air Force and Navy installations that had missing data was estimated by multiplying the known or estimated water consumption of each base by the correlation factor of 0.6279.

Navy Utility Information

Activity breakout by the Navy proved to be troublesome regarding utility information. In some cases, one activity was billed for other activities within the same installation or for activities outside of the installation. After careful scrutiny of activity billing, utility information was separated effectively. Dan Rydberg of Naval Facilities Engineering Services Center (NFESC) provided Navy Utility data from the Utility Procurement Analysis (UPA) database.

Electrical costs and consumption for fiscal year 1992 were taken from the UPA and Base Support database or given average values until information becomes available. The costs and consumption for each activity at each installation were added to produce a generic unit cost of electricity for the base.

Water and sewer service figures for fiscal year 1992 were taken from the UPA database. The base's total water consumption was determined by adding up the consumption by the individual suppliers. The largest supplier was determined from the database and the unit cost for that supplier was used in the model.

Appendix C: Weather Information

Location-Specific Weather Data Used in the REEP Model

City and State

For each Army, Air Force, and Navy installation, the city and state were established using a Major Military Installations Map from January 1, 1985.

Latitude, Longitude, and Elevation

The Weather Data Manual (Department of the Army Technical Manual [TM] 5-785) provided the latitude, longitude, and elevation.

Heating and Cooling Degree Days

The Weather Data Manual (TM 5-785) provided 30-year average annual Heating and Cooling Degree Days using a base of 65 °F.

Winter and Summer Design Temperatures

Exterior design temperatures were also obtained from the Weather Data Manual (TM 5-785). Exterior winter design temperatures are dry bulb temperatures that are equaled or exceeded 97.5 pecent of the time, on average, during the coldest 3 consecutive months (standardized as December, January, and February). Exterior summer design temperatures are dry and wet bulb temperatures that are equaled or exceeded 2.5 percent of the time, on average, during the warmest 4 consecutive months, as determined from the monthly mean wet bulb temperature (standardized as June, July, August, and September).

Annual Hours of Dry and Wet Bulb Temperatures and the AC Logic Test

Facilities, except if exempted, can only qualify for air conditioning in locations where (during the 6 warmest months of the year) the dry bulb temperature is 80 °F or higher for over 650 hours, or the wet bulb temperature is 67 °F or higher for over 800 hours (AEI 1991). The number of hours that the dry bulb temperatures of 80 °F and the wet

bulb temperatures of 67 °F are equaled or exceeded during the warmest 6 consecutive months (standardized as May through October) were obtained from the Weather Data Manual (TM 5-785). Using these criteria and data, the REEP AC Logic Test determines which installations are authorized to air condition.

Mean Coincident Wet Bulb

The Mean Coincident Wet Bulb (MCWB) temperature value is the mean value of all those wet bulb temperatures which occur coincidently with the dry bulb temperatures in the particular 5 degree temperature interval. This information was provided by the Weather Data Manual (TM 5-785).

Mean Daily Range

The Mean Daily Range was also found in the Weather Data Manual (TM 5-785) for the three military branches, and is the average of all daily dry bulb temperature ranges for days on which the 2.5 percent dry bulb summer design temperature is reached or exceeded.

Bin Data

For various calculations in the HVAC and Renewables section of the REEP model, a series of bin data was taken from the Weather Data Manual (TM 5-785). The annual total number of hours observed above the 60/64 temperature range, within the 80/84 temperature range, and within the 85/89 temperature range were established. Also the MCWB temperature for the 80/84 temperature range and the 85/89 temperature range were noted for the model.

Total Global Radiation

Total global radiation was obtained from the Insolation Data Manual (Solar Energy Research Institute, October 1982). These insolation values represent monthly average daily totals of global radiation on a horizontal surface in Btu/sq ft day units.

Passive Solar Design Factor

A weather parameter for passive solar design of solar radiation / HDD was taken from Design Procedures for Passive Solar Buildings (Military Handbook [M-Hdbk] 1003/19).

Heating and Cooling Factors

Heating and cooling factors were generated from a formula based on tables established in *Guide for Estimating Differences in Building Heating and Cooling Energy Due to Changes in Solar Reflectance of a Low-Sloped Roof* (Oak Ridge National Laboratory, August 1989).

Fraction of Annual Lighting Heat to Cooling and Heating

The fractions of annual lighting heat to cooling and heating were obtained for each installation from a table established in "Guide to Simplified Lighting/HVAC Interaction Calculations" (Rundquist, undated).

Ground Temperature

The ground temperature for each installation was estimated using a formula generated from regressions run on a table of ground temperatures at various HDD. The established table values were obtained from *The Site Energy Handbook* (Energy Research and Development Administration, 1976).

Number of Heating and Cooling Season Days

Some of the REEP ECO algorithms require an estimate of the number of days per year that heating or cooling would be required at an installation. These values are based on a methodology and algorithms developed at USACERL. This section details how these estimates were derived.

Twenty-six BLAST weather files were processed using the Weather Information File Encoder (WIFE) to obtain the following climate information: Average Daily Maximum Temperature (per month), Average Daily Minimum Temperature (per month), and Average Daily Diurnal Swing (°F). The 26 weather files represent a diverse selection of climate types ranging from cold to temperate to dry and hot to humid and hot.

The first task was to determine the number of hours per day that heating would be required during the heating season and cooling would be required during the cooling season. The method used to determine these values is similar for both heating and cooling. It was assumed that cooling starts at 75 °F and that the average daily maximum temperature for the month is the peak temperature used for the calculations. The difference between these two values is multiplied by 24 hours and then divided by the average daily diurnal swing. A large diurnal swing would reduce

the cooling requirements while a small diurnal swing would increase the number of hours cooling is called for. The following equation depicts the calculation of the number of hours per day cooling is required.

$$\text{Cooling: Hours per Day} = \frac{(T_{ADMax} - T_{CS}) \times 24}{T_{ADDS}}$$

$$\text{Heating: Hours per Day} = \frac{(T_{HS} - T_{ADMin}) \times 24}{T_{ADDS}}$$

where:

T_{ADMax} = Average Daily Maximum Temperature (per month)

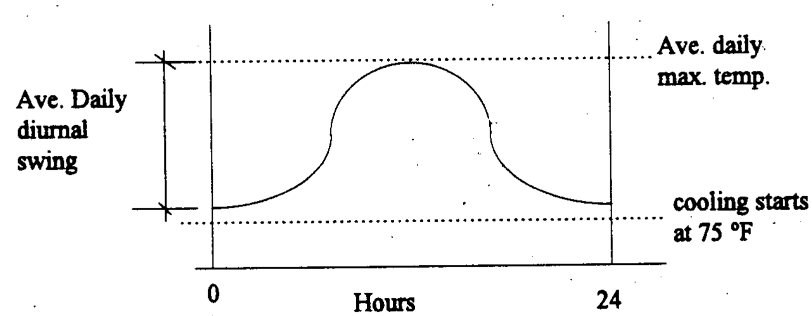
T_{ADMin} = Average Daily Minimum Temperature (per month)

T_{ADDS} = Average Daily Diurnal Swing (°F)

T_{CS} = Temperature cooling starts at (assumed to be 75 °F)

T_{HS} = Temperature heating starts at (assumed to be 60 °F)

Note: Depending on maximum, minimum, and diurnal swing temperatures, both equations can exceed 24 hours per day; therefore, the number of heating and cooling hours per day is limited to a maximum of 24.



The numbers of cooling hours per month and cooling days per month were calculated as follows:

Cooling hours per month = Cooling hours per day x Number of days per month

Cooling days per month = Cooling hours per month ÷ Number of days per month

Number of days of heating per month were calculated similarly.

Following are example results from two installations to which these calculations were applied.

Ft. Hood

Start cooling at 75.00
Start heating at 60.00

Month	Days per month	Ave. Daily Diurnal Swing	Ave. Daily Max. Temp	Ave. Daily Min. Temp	Cooling Hours per day	Cooling Hours per month	Heating Hours per day	Heating Hours per month	Days of Cooling per month	Days of Heating per month
jan	31.00	14.10	55.20	41.10	-33.70	-1044.77	24.00	744.00	0.00	31.00
feb	28.00	18.40	57.20	38.80	-23.22	-650.09	24.00	672.00	0.00	28.00
march	31.00	18.80	67.30	48.40	-9.83	-304.72	14.81	459.06	0.00	19.13
april	30.00	16.50	75.00	58.50	0.00	0.00	2.18	65.45	0.00	2.73
may	31.00	16.60	81.60	65.00	9.54	295.81	-7.23	-224.10	12.33	0.00
june	30.00	15.30	87.20	71.90	19.14	574.12	-18.67	-560.00	23.92	0.00
july	31.00	21.50	96.10	74.60	23.55	730.16	-16.30	-505.23	30.42	0.00
aug	31.00	22.20	95.20	73.00	21.84	676.97	-14.05	-435.68	28.21	0.00
sept	30.00	17.10	83.20	66.10	11.51	345.26	-8.56	-256.84	14.39	0.00
oct	31.00	21.20	79.00	57.80	4.53	140.38	2.49	77.21	5.85	3.22
nov	30.00	19.50	69.40	50.00	-6.89	-206.77	12.31	369.23	0.00	15.38
dec	31.00	17.70	59.30	41.60	-21.29	-659.93	24.00	744.00	0.00	31.00
									115.11	130.46

Colorado Springs

Start cooling at 75.00
Start heating at 60.00

Month	Days per month	Ave. Daily Diurnal Swing	Ave. Daily Max. Temp	Ave. Daily Min. Temp	Cooling Hours per day	Cooling Hours per month	Heating Hours per day	Heating Hours per month	Days of Cooling per month	Days of Heating per month
jan	31.00	25.5	44.1	18.6	-29.08	-901.55	24.00	744.00	0.00	31.00
feb	28.00	24.6	45.2	20.6	-29.07	-814.05	24.00	672.00	0.00	28.00
march	31.00	25.8	49	23.2	-24.19	-749.77	24.00	744.00	0.00	31.00
april	30.00	22.3	57	34.7	-19.37	-581.17	24.00	720.00	0.00	30.00
may	31.00	24.4	68.6	44.2	-6.30	-195.15	15.54	481.77	0.00	20.07
june	30.00	26.1	78.2	52.1	2.94	88.28	7.26	217.93	3.68	9.08
july	31.00	24	83	59	8.00	248.00	1.00	31.00	10.33	1.29
aug	31.00	24.5	81.6	57.2	6.47	200.42	2.74	85.03	8.35	3.54
sept	30.00	27.1	76.7	49.6	1.51	45.17	9.21	276.31	1.88	11.51
oct	31.00	24.2	65.1	40.8	-9.82	-304.36	19.04	590.28	0.00	24.60
nov	30.00	22.7	49.8	27.1	-26.64	-799.30	24.00	720.00	0.00	30.00
dec	31.00	26.1	47.5	21.4	-25.29	-783.91	24.00	744.00	0.00	31.00
									24.24	251.10

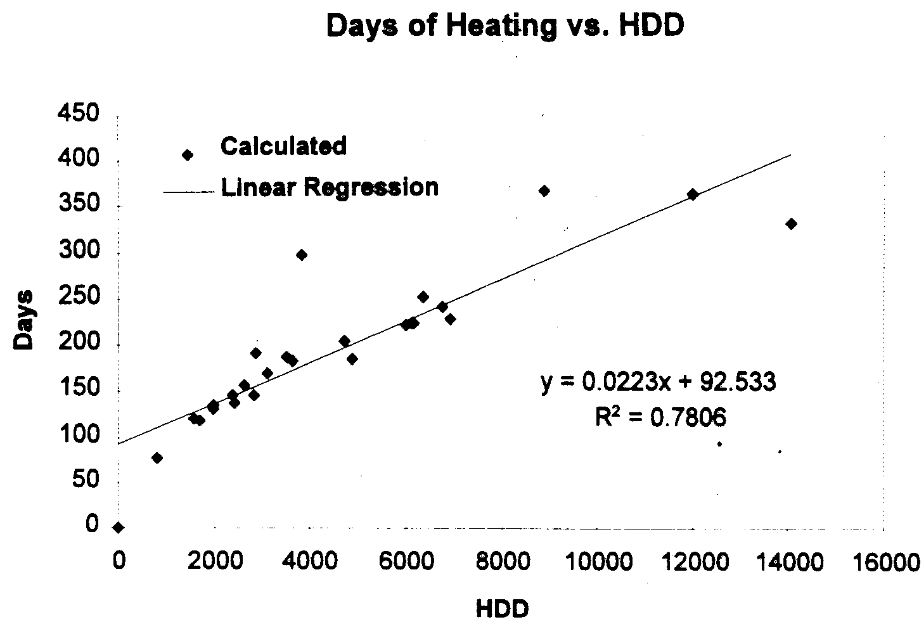
These calculations were performed on the 26 weather files, and regressions were run on the number of days of heating and cooling versus HDD and CDD respectively. The regressions were used to develop algorithms that could be applied to the remaining installations HDD and CDD to generate number of days of heating and cooling per

year. Following are the results from these calculations and graphs of the regression equations.

	HDD	Calculated Days of Htg/Yr	*Predicted Y*	*Residuals*
1 Honolulu	0	0	93	-93
2 Yuma	790	77	110	-33
3 San Antonio	1570	121	127	-6
4 Mobile	1684	118	130	-12
5 Ft. Hood	1959	130	136	-6
6 Savanah	1988	136	137	-1
7 Ft. Worth	2387	147	146	1
8 El Paso	2432	139	147	-8
9 Augusta	2605	157	151	6
10 Texarkana	2834	147	156	-9
11 Sacramento	2843	191	156	35
12 Atlanta	3095	170	161	8
13 Raleigh	3514	188	171	17
14 Chattanoga	3638	184	174	10
15 Ft. Ord	3813	296	177	119
16 Wash. D.C.	4733	205	198	7
17 Ft. Riley	4884	185	201	-16
18 Detroit	6023	222	227	-5
19 Burlington	6130	223	229	-6
20 Chicago	6158	223	230	-7
21 Colo. Springs	6373	251	234	17
22 Albany	6783	241	244	-3
23 Ft. McCoy	6917	229	246	-17
24 Adak	8908	365	291	74
25 King Salmon	12011	361	360	1
26 Big Delta	14068	329	406	-77

Days of heating - Constant not through zero

Regression Statistics	
Multiple R	0.8835
R Square	0.780572
Adjusted R Square	0.771429
Standard Error	39.95597
Observations	26

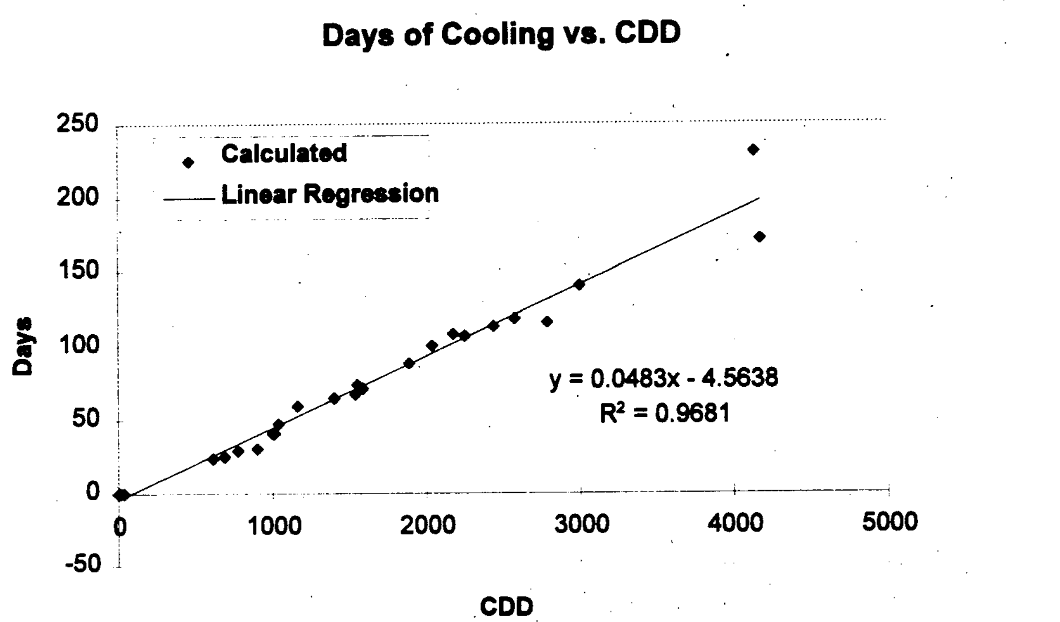


	CDD	Days of Clg/Yr	*Predicted Y*	*Residuals*
1 Adak	0	0	-5	5
2 King Salmon	4	0	-4	4
3 Big Delta	16	0	-4	4
4 Ft. Ord	37	0	-3	3
5 Albany	613	23	25	-2
6 Colo. Springs	692	24	29	-5
7 Ft. McCoy	779	29	33	-4
8 Detroit	903	30	39	-9
9 Burlington	998	40	44	-4
10 Chicago	1014	40	44	-4
11 Wash. D.C.	1039	46	46	1
12 Sacramento	1159	59	51	8
13 Raleigh	1394	64	63	1
14 Chattanoga	1532	67	69	-2
15 Ft. Riley	1551	73	70	3
16 Atlanta	1589	71	72	-2
17 Augusta	1892	87	87	0
18 Texarkana	2040	99	94	5
19 Savanah	2177	107	101	6
20 El Paso	2253	106	104	2
21 Ft. Worth	2436	112	113	-1
22 Mobile	2577	117	120	-3
23 Ft. Hood	2792	115	130	-15
24 San Antonio	2994	140	140	0
25 Honolulu	4140	231	195	36
26 Yuma	4180	171	197	-26

Days of cooling - Constant not through zero

Regression Statistics

Multiple R	0.98394118
R Square	0.96814024
Adjusted R Square	0.96681275
Standard Error	10.343493
Observations	26



Wind Power Class

The wind power classes for each installation for all three military branches were obtained from *Wind Energy Resource Atlas of the United States* (U.S. Department of Energy, March 1987).

Appendix D: Individual ECO/WCO Summaries

Electrical

The electrical category in REEP provides the means to analyze the potential of small (1 to 10 horsepower), medium (10 to 20 horsepower), and large (over 20 horsepower) high-efficiency motors and adjustable speed drives (ASDs). Motor driven systems consume an estimated 40 to 60 percent of the electrical energy in a typical building. Improving motor efficiency or its ability to respond to loading conditions can save a substantial amount of energy.

Induction motors are relatively efficient devices for converting electrical energy to rotational energy. The high efficiency polyphase AC induction motors typically range in full load efficiency from 87 to 95 percent. The upper limit of available full load efficiency increases as the rated horsepower increases, but is also affected by enclosure type, synchronous speed, and several other motor variables. High efficiency motors have been commercially available for many years. However, specification and use of high efficiency motors has been limited by a variety of real and perceived problems. High efficiency motors typically cost about 20 percent more than the comparable standard efficiency motor. This increased initial cost is quickly paid back through reduced energy costs because the motor driven system consumes many times the initial cost of the motor in electrical energy every year, and motors have a typical life expectancy of 20 years. Integral horsepower motors should be high efficiency if they (1) operate at least 2,000 hours per year with electric costs of at least 2 cents per killowatt-hour, or (2) operate during on-peak times in areas where the demand charge is a significant part of the annual electrical energy cost. Delivery times and availability are no longer a real consideration when deciding whether to specify and install an energy efficient motor. Harsh environments where motor life is very short or applications where the increased speed of the energy efficient motor would negate the energy savings are typical exceptions to using high efficiency motors for any integral horsepower motor application.

> "One of the most energy-intensive activities of HVAC systems is the operation of pumps and fans. Frequently, when a thermostat or other energy management control device signals the HVAC system to increase or decrease the temperature in a building, the HVAC system operates at full power. This is

> seldom needed. Since frequent operation of a pump or fan at a low rate consumes less energy than infrequent operation of a pump or fan at a high flow rate, the installation of a motor that varies its speed saves energy. These motors are called adjustable speed drives." (From *Energy Ideas*, Center for Study of Responsive Law, December 1992.)

Depending on the situation, ASDs can reduce energy consumption up to 60 percent. Although ASDs can be used for a variety of applications, for the REEP model they have only been considered as a retrofit for ventilation motors. Other applications for ASDs would have been difficult to derive from available information.

High Efficiency Motors (small, medium, large)

Background. Advances in electric motor designs and materials have led to higher motor efficiencies. This ECO specifically examines the energy saving attributed to replacing existing motors with high efficiency replacements. The motors have been divided into three size ranges for this analysis. Small motors range from 1 to 10 horsepower. Medium sized motors cover the range of 10 to 20 horsepower. Large motors are over 20 horsepower. Because motors are classified into three different categories, three different ECOs have been developed for this technology.

Facility assumptions. The facilities included for this analysis were training, administration, hospital/medical, and community-type facilities.

Motor algorithms. The electrical consumption saved by replacing a motor with a high efficiency motor is due to the delta in efficiencies. The increase in efficiency times the size of the motor multiplied by the number of hours of operation results in the savings in electrical consumption for one motor. The demand saving is also based on the delta in the motors' efficiencies.

Assumptions file (large).

```
REEP ECO REPORT                                              Page 1
09/01/94

ECO:  High Eff Motors (Large)

FIELD       DESCRIPTION                                       VALUE
-------------------------------------------------------------------
ECO         Energy Opportunity                High Eff Motors (Large)
UNIT        Unit                                             Motors
ECOTYPE     Energy Opportunity Type                      Electrical
PROGRAM     Rules File (Program) Name                      ventmotl
CAPCOST     Capital Cost                                    1550.00
```

RECURCOST	Recurring Cost	1.00
ECONLIFE	Economic Life	20.00
DISCQTY	Discount Quantity	10.00
ASSUM01	ECO Assumption 01	Square feet per motor (ksf)
ASSUM01V	ECO Assumption 01 Value	56.07
ASSUM02	ECO Assumption 02	Percent of floor area affected
ASSUM02V	ECO Assumption 02 Value	100.00
ASSUM03	ECO Assumption 03	Annual kWh savings per motor
ASSUM03V	ECO Assumption 03 Value	7470.95
ASSUM04	ECO Assumption 04	kW savings
ASSUM04V	ECO Assumption 04 Value	1.60

Rules file (large).

```
* This is the ventmotl.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with ( ( xtraare + xhosmedare + xadmare + xbarare +  ;
        xcomfacare ) / xassum01v ) * ( xassum02v / 100 ) ;
        * ( 1 - penfac )

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
```

```
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with ( numecouni * xassum03v * 3.412 ) / 1000

* eleenesav end


********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with numecouni * xassum04v

* basdemsav end

******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********
```

```
* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

***** Calculate Lbs. of CFCs displaced *******

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start
```

```
replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Assumptions file (medium).

```
REEP ECO REPORT                                                 Page 1
09/01/94

ECO:  High Eff Motors (Medium)

FIELD      DESCRIPTION                                           VALUE
-----------------------------------------------------------------------
ECO         Energy Opportunity                 High Eff Motors (Medium)
UNIT        Unit                                                 Motors
ECOTYPE     Energy Opportunity Type                          Electrical
PROGRAM     Rules File (Program) Name                          ventmotm
CAPCOST     Capital Cost                                         950.00
RECURCOST   Recurring Cost                                         1.00
ECONLIFE    Economic Life                                         20.00
DISCQTY     Discount Quantity                                     20.00
ASSUM01     ECO Assumption 01               Square feet per motor (ksf)
ASSUM01V    ECO Assumption 01 Value                               49.41
ASSUM02     ECO Assumption 02            Percent of floor area affected
ASSUM02V    ECO Assumption 02 Value                              100.00
ASSUM03     ECO Assumption 03               Annual kWh savings per motor
ASSUM03V    ECO Assumption 03 Value                             4583.45
ASSUM04     ECO Assumption 04                                 kW savings
ASSUM04V    ECO Assumption 04 Value                                0.98
```

Rules file (medium).

```
* This is the ventmotm.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
```

```
   with ( ( xtraare + xhosmedare + xadmare + xbarare +  ;
        xcomfacare ) / xassum01v ) * ( xassum02v / 100 ) ;
        * ( 1 - penfac )

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with ( numecouni * xassum03v * 3.412 ) / 1000

* eleenesav end


********** calculate base load fuel saved **********

* basdemsav start
```

```
replace basdemsav ;
   with numecouni * xassum04v

* basdemsav end

******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

**** Calculate Lbs. of CFCs displaced *****
```

```
* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Assumptions file (small).

```
REEP ECO REPORT                                              Page 1
09/01/94

ECO:  High Eff Motors (Small)

FIELD       DESCRIPTION                                       VALUE
-------------------------------------------------------------------
ECO         Energy Opportunity              High Eff Motors (Small)
UNIT        Unit                                             Motors
ECOTYPE     Energy Opportunity Type                      Electrical
PROGRAM     Rules File (Program) Name                      ventmots
CAPCOST     Capital Cost                                     450.00
RECURCOST   Recurring Cost                                     1.00
ECONLIFE    Economic Life                                     20.00
DISCQTY     Discount Quantity                                 30.00
```

ASSUM01	ECO Assumption 01	Square feet per motor (ksf)
ASSUM01V	ECO Assumption 01 Value	4.68
ASSUM02	ECO Assumption 02	Percent of floor area affected
ASSUM02V	ECO Assumption 02 Value	100.00
ASSUM03	ECO Assumption 03	Annual kWh savings per motor
ASSUM03V	ECO Assumption 03 Value	1635.81
ASSUM04	ECO Assumption 04	kW Savings
ASSUM04V	ECO Assumption 04 Value	0.35

Rules file (small).

```
* This is the ventmots.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with ( ( xtraare + xhosmedare + xadmare + xbarare + ;
        xcomfacare ) / xassum01v ) * ( xassum02v / 100 ) ;
        * ( 1 - penfac )

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end
```

```
********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with ( numecouni * xassum03v * 3.412 ) / 1000

* eleenesav end

********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with numecouni * xassum04v

* basdemsav end

******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0
```

```
* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

***** Calculate Lbs. of CFCs displaced *****

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end
```

```
do comcalc2

*  SECTION 3 - ECO specific calculations that override common
calculations
```

Adjustable Speed Drives on Air Handler/Ventilation Motors

Background. Advances in electric motor control designs have resulted in the adjustable speed drive (ASD). The drive can be retrofitted to existing motors and allows the motor to adjust to meet the load. This ECO specifically examines the energy savings attributed to retrofitting existing motors with an ASD controller. The ventilation motors have been divided into three size ranges for this analysis. Small motors range from 1 to 10 horsepower (HP). Medium sized ventilation motors range from 10 to 20 HP. Large motors are over 20 HP. Because of the classification of motors into three different categories, three different ECOs have been developed for this technology.

Ventilation motor characteristics. Table D1 lists the important ventilation motor characteristics. For this analysis, the ventilation fan was assumed to be forward curved with variable inlet vanes. The table lists the typical system parameters for the three motor size ranges.

Table D2 lists the motor efficiencies and motor densities for the three size classes (Pacific Northwest Laboratory 1992). The table also lists installed costs for ASDs for the three sizes of motor classes.

Facility assumptions. The facilities included for this analysis were training, administration, hospital/medical, and community-type facilities.

Hours of operation each day	18	Hrs/Day	
Days of operation each year	260	days/Yr	(5 days/week x 52 weeks/Yr)

Adjustable speed drive algorithms. Table D1 listing system parameters were used to develop a regressional equation describing the variation of horsepower required to drive the fan versus flow in the system. Equations were developed for both the original system and the system retrofitted with an ASD.

Table D1. Ventilation motor characteristics.

Forward Curved										
VIV		41800	2.8		25		ASD- VIV			
Flow	Pressure	% Max CFM	% Max SP	% Max HP	HP	Efficiency	Flow	Pressure	HP	Efficiency
27500	2.3	65.79%	82.14%	100.00%	25.0	39.80%	27500	2.3	25	39.80%
25000	2	59.81%	71.43%	86.96%	21.7	36.19%	25000	2	19.5	40.34%
22500	1.75	53.83%	62.50%	76.09%	19.0	32.57%	22500	1.75	14.8	41.86%
20000	1.5	47.85%	53.57%	65.22%	16.3	28.95%	20000	1.5	10.5	44.95%
17500	1.3	41.87%	46.43%	56.52%	14.1	25.33%	17500	1.3	7.55	47.41%
15000	1.12	35.89%	40.00%	48.70%	12.2	21.71%	15000	1.12	5.3	49.87%
12500	0.96	29.90%	34.29%	41.74%	10.4	18.09%	12500	0.96	3.5	53.94%
10000	0.8	23.92%	28.57%	34.78%	8.7	14.47%	10000	0.8	2.2	57.21%
VIV		22000	3.2		15		ASD- VIV			
Flow	Pressure	% Max CFM	% Max SP	% Max HP	HP	Efficiency	Flow	Pressure	HP	Efficiency
15000	2.5	68.18%	78.13%	100.00%	15.0	39.33%	15000	2.5	15	39.33%
14000	2.25	63.64%	70.31%	90.00%	13.5	36.71%	14000	2.25	12.6	39.33%
12000	1.85	54.55%	57.81%	74.00%	11.1	31.47%	12000	1.85	8.4	41.58%
10000	1.5	45.45%	46.88%	60.00%	9.0	26.22%	10000	1.5	5.5	42.91%
8000	1.2	36.36%	37.50%	48.00%	7.2	20.98%	8000	1.2	3	50.35%
6000	0.9	27.27%	28.13%	36.00%	5.4	15.73%	6000	0.9	1.6	53.10%
VIV		10500	2.3		5.0		ASD- VIV			
Flow	Pressure	% Max CFM	% Max SP	% Max HP	HP	Efficiency	Flow	Pressure	HP	Efficiency
7000	1.8	66.67%	78.26%	100.00%	5.0	39.65%	7000	1.8	5	39.65%
6500	1.6	61.90%	69.57%	88.89%	4.4	36.82%	6500	1.6	4	40.91%
6000	1.4	57.14%	60.87%	77.78%	3.9	33.98%	6000	1.4	3.2	41.30%
5500	1.3	52.38%	56.52%	72.22%	3.6	31.15%	5500	1.3	2.7	41.66%
5000	1.22	47.62%	53.04%	67.78%	3.4	28.32%	5000	1.22	2.1	45.70%
4500	1.1	42.86%	47.83%	61.11%	3.1	25.49%	4500	1.1	1.6	48.67%
4000	0.98	38.10%	42.61%	54.44%	2.7	22.66%	4000	0.98	1.25	49.34%
3500	0.86	33.33%	37.39%	47.78%	2.4	19.82%	3500	0.86	0.95	49.85%

Table D2. Ventilation motor efficiencies and densities.

	Small (1 - 10 HP)	Medium (10 - 20 HP)	Large (>20 HP)
Standard Efficiency (%)	83	86	87
Motor Density (KSF/motor)	1.8	9.0	45.0
Installed Cost ($)	1,950	4,850	7,250
Algorithm HP	5	15	25
Economic Life	20 yr		
Recurring Cost	0		

25 HP System	Original System:	HP	= -1.32765 + 0.000921 x Flow
	ASD Retrofit:	HP	= -13.1571 + 0.001291 x Flow
15 HP System	Original System:	HP	= -1.23288 + 0.001055 x Flow
	ASD Retrofit:	HP	= -8.59041 + 0.001502 x Flow
5 HP System	Original System:	HP	= -0.13889 + 0.000705 x Flow
	ASD Retrofit:	HP	= -3.3375 + 0.001131 x Flow

Annual megawatt hour (MWH) savings per motor is based on 24 daily periods of constant loading at different levels. The loading profile is assumed as follows:

Load Profile:

%Flow	53	53	52	50	48	52	63	77	91	97	97	95	95	98	100	97	88	78	70	66	65	63	60	56
%Time	5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5

The HP required to meet the flow is calculated using the regression equations for the original system and for the system retrofitted with an ASD. The MWH usage for each time period for both systems is calculated by:

$$MWH = \%\ time \ \times \ H \ \times \ 0.746 \ \times \ HP$$

The MWH savings for each period is calculated by the following:

$$MWH_s = MWH_o - MWH_{asd}$$

The Annual MWH savings per ASD = Sum of the MWHs for each period.

where:

% time	= Time of the total operating hours this period represents
H	= Hours of operation per year
HP	= Horsepower required to meet the flow for the time period
MWHs	= MWH saved during each time period
MWHo	= MWH consumed by the original system during the time period

MWHasd = MWH consumed by the system retrofitted with the ASD.

Ventilation motor conclusions. In many instances, the retrofit of an ASD does result in a simple payback of less than 10 years. This analysis is very sensitive to the type of fan selected, designed flow, and designed static pressure.

Assumptions file (motors > 20 HP).

```
REEP ECO REPORT                                                Page 1
09/01/94

ECO:  Ventln Motor ASD (Large)

FIELD      DESCRIPTION                                          VALUE
----------------------------------------------------------------------
ECO        Energy Opportunity                  Ventln Motor ASD (Large)
UNIT       Unit                                                  Motors
ECOTYPE    Energy Opportunity Type                           Electrical
PROGRAM    Rules File (Program) Name                           adjuspel
CAPCOST    Capital Cost                                         6000.00
RECURCOST  Recurring Cost                                          1.00
ECONLIFE   Economic Life                                          10.00
DISCQTY    Discount Quantity                                      10.00
ASSUM01    ECO Assumption 01          KSF per ASD for Installation w/
ASSUM01V   ECO Assumption 01 Value                              3245.50
ASSUM02    ECO Assumption 02                      % of ASD applications
ASSUM02V   ECO Assumption 02 Value                                 0.30
ASSUM03    ECO Assumption 03                    Annual hours of operation
ASSUM03V   ECO Assumption 03 Value                              6552.00
ASSUM04    ECO Assumption 04                  HVAC cooling energy credit
ASSUM04V   ECO Assumption 04 Value                                 0.00
ASSUM05    ECO Assumption 05                 HVAC cooling demand savings
ASSUM05V   ECO Assumption 05 Value                                 0.00
ASSUM06    ECO Assumption 06                   Existing motor efficiency
ASSUM06V   ECO Assumption 06 Value                                 0.87
ASSUM07    ECO Assumption 07                           AVG HP for range
ASSUM07V   ECO Assumption 07 Value                                25.00
ASSUM08    ECO Assumption 08                                      KW/HP
ASSUM08V   ECO Assumption 08 Value                               746.00
ASSUM09    ECO Assumption 09                          VIV System Flow CFM
ASSUM09V   ECO Assumption 09 Value                             27500.00
ASSUM10    ECO Assumption 10         KSF per ASD for Installations w
ASSUM10V   ECO Assumption 10 Value                               371.85
```

Rules file (motors > 20 HP).

```
* This is the adjuspel.prg program

* SECTION 1 - ECO specific calculations
```

```
********** Select the Penetration Factor **********

do comcalc

dimension perflow(24)
dimension pertime(24)
dimension mtreff(24)
dimension asdeff(24)

perflow(1) = 53
perflow(2) = 53
perflow(3) = 52
perflow(4) = 50
perflow(5) = 48
perflow(6) = 52
perflow(7) = 63
perflow(8) = 77
perflow(9) = 91
perflow(10) = 97
perflow(11) = 97
perflow(12) = 95
perflow(13) = 95
perflow(14) = 98
perflow(15) = 100
perflow(16) = 97
perflow(17) = 88
perflow(18) = 78
perflow(19) = 70
perflow(20) = 66
perflow(21) = 65
perflow(22) = 63
perflow(23) = 60
perflow(24) = 56

pertime(1) = 5
pertime(2) = 5
pertime(3) = 4
pertime(4) = 4
pertime(5) = 4
pertime(6) = 4
pertime(7) = 4
pertime(8) = 4
pertime(9) = 4
pertime(10) = 4
pertime(11) = 4
pertime(12) = 4
pertime(13) = 4
pertime(14) = 4
pertime(15) = 4
pertime(16) = 4
pertime(17) = 4
```

```
pertime(18) = 4
pertime(19) = 4
pertime(20) = 4
pertime(21) = 4
pertime(22) = 4
pertime(23) = 5
pertime(24) = 5

mtreff(1) = 75 * xassum06v / .87
mtreff(2) = 75 * xassum06v / .87
mtreff(3) = 75 * xassum06v / .87
mtreff(4) = 73 * xassum06v / .87
mtreff(5) = 72 * xassum06v / .87
mtreff(6) = 75 * xassum06v / .87
mtreff(7) = 83 * xassum06v / .87
mtreff(8) = 85 * xassum06v / .87
mtreff(9) = 86 * xassum06v / .87
mtreff(10) = 87 * xassum06v / .87
mtreff(11) = 87 * xassum06v / .87
mtreff(12) = 87 * xassum06v / .87
mtreff(13) = 87 * xassum06v / .87
mtreff(14) = 87 * xassum06v / .87
mtreff(15) = 87 * xassum06v / .87
mtreff(16) = 87 * xassum06v / .87
mtreff(17) = 86 * xassum06v / .87
mtreff(18) = 86 * xassum06v / .87
mtreff(19) = 84 * xassum06v / .87
mtreff(20) = 84 * xassum06v / .87
mtreff(21) = 84 * xassum06v / .87
mtreff(22) = 83 * xassum06v / .87
mtreff(23) = 81 * xassum06v / .87
mtreff(24) = 77 * xassum06v / .87

asdeff(1) = 89
asdeff(2) = 89
asdeff(3) = 89
asdeff(4) = 88
asdeff(5) = 88
asdeff(6) = 89
asdeff(7) = 91
asdeff(8) = 93
asdeff(9) = 95
asdeff(10) = 96
asdeff(11) = 96
asdeff(12) = 96
asdeff(13) = 96
asdeff(14) = 96
asdeff(15) = 96
asdeff(16) = 96
asdeff(17) = 95
asdeff(18) = 94
```

```
asdeff(19) = 92
asdeff(20) = 91
asdeff(21) = 91
asdeff(22) = 91
asdeff(23) = 90
asdeff(24) = 90

mwh = 0
asdmwh = 0

FOR count = 1 to 24

mwh = mwh + ( -1.32765 + 0.000921 * ( perflow(count) / 100 ) ;
 * xassum09v ) / xassum06v * xassum08v * ( pertime(count) / 100 ) ;
 * xassum03v /1000000

asdmwh = asdmwh + ( -13.1571 + 0.001291 * ( perflow(count) / 100 ) ;
 * xassum09v ) / ( mtreff(count) / 100 ) * ( asdeff(count) / 100 ) ;
 * xassum08v * ( pertime(count) / 100 ) * xassum03v / 1000000

ENDFOR

savemwh = mwh - asdmwh

********** calculate number of ECO units **********

* numecouni start

if xaclogtst = 0
    replace numecouni ;
            with ( ( xtraare + xhosmedare + xadmare + xbarare + ;
        xcomfacare ) / xassum01v ) * xassum02v ;
        * ( 1 - penfac )
else
    replace numecouni ;
            with ( ( xtraare + xhosmedare + xadmare + xbarare + ;
        xcomfacare ) / xassum10v ) * xassum02v ;
        * ( 1 - penfac )
endif

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
```

```
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with mwh

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with asdmwh

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with ( numecouni * savemwh * 3.412 )

* eleenesav end

********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with  0

* basdemsav end

******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate gas fuel saved **********
```

```
* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

**** Calculate Lbs. of CFCs displaced ****

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start
```

```
replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Assumptions file (10-20 HP).

REEP ECO REPORT Page 1
09/01/94

ECO: Ventln Motor ASD (Medium)

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	Ventln Motor ASD (Medium)
UNIT	Unit	Motors
ECOTYPE	Energy Opportunity Type	Electrical
PROGRAM	Rules File (Program) Name	adjuspem
CAPCOST	Capital Cost	3250.00
RECURCOST	Recurring Cost	1.00
ECONLIFE	Economic Life	10.00
DISCQTY	Discount Quantity	10.00
ASSUM01	ECO Assumption 01	KSF per ASD for Installations w
ASSUM01V	ECO Assumption 01 Value	21.60
ASSUM02	ECO Assumption 02	% of ASD applications
ASSUM02V	ECO Assumption 02 Value	0.30
ASSUM03	ECO Assumption 03	Annual hours of operation
ASSUM03V	ECO Assumption 03 Value	6552.00
ASSUM04	ECO Assumption 04	HVAC cooling energy credit
ASSUM04V	ECO Assumption 04 Value	0.00
ASSUM05	ECO Assumption 05	HVAC cooling demand credit
ASSUM05V	ECO Assumption 05 Val	0.00
ASSUM06	ECO Assumption 06	Existing motor efficiency
ASSUM06V	ECO Assumption 06 Value	0.86
ASSUM07	ECO Assumption 07	AVG HP for range
ASSUM07V	ECO Assumption 07 Value	15.00
ASSUM08	ECO Assumption 08	W/HP

ASSUM08V	ECO Assumption 08 Value	746.00
ASSUM09	ECO Assumption 09	VIV System Flow CFM
ASSUM09V	ECO Assumption 09 Value	15000.00
ASSUM10	ECO Assumption 10	KSF per ASD for Installations w
ASSUM10V	ECO Assumption 10 Value	176.63

Rules file (10-20 HP).

```
* This is the adjuspem.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

dimension perflow(24)
dimension pertime(24)
dimension mtreff(24)
dimension asdeff(24)

perflow(1) = 53
perflow(2) = 53
perflow(3) = 52
perflow(4) = 50
perflow(5) = 48
perflow(6) = 52
perflow(7) = 63
perflow(8) = 77
perflow(9) = 91
perflow(10) = 97
perflow(11) = 97
perflow(12) = 95
perflow(13) = 95
perflow(14) = 98
perflow(15) = 100
perflow(16) = 97
perflow(17) = 88
perflow(18) = 78
perflow(19) = 70
perflow(20) = 66
perflow(21) = 65
perflow(22) = 63
perflow(23) = 60
perflow(24) = 56

pertime(1) = 5
pertime(2) = 5
pertime(3) = 4
pertime(4) = 4
pertime(5) = 4
```

```
pertime(6) = 4
pertime(7) = 4
pertime(8) = 4
pertime(9) = 4
pertime(10) = 4
pertime(11) = 4
pertime(12) = 4
pertime(13) = 4
pertime(14) = 4
pertime(15) = 4
pertime(16) = 4
pertime(17) = 4
pertime(18) = 4
pertime(19) = 4
pertime(20) = 4
pertime(21) = 4
pertime(22) = 4
pertime(23) = 5
pertime(24) = 5

mtreff(1) = 73 * xassum06v / .86
mtreff(2) = 73 * xassum06v / .86
mtreff(3) = 73 * xassum06v / .86
mtreff(4) = 71 * xassum06v / .86
mtreff(5) = 70 * xassum06v / .86
mtreff(6) = 73 * xassum06v / .86
mtreff(7) = 80 * xassum06v / .86
mtreff(8) = 84 * xassum06v / .86
mtreff(9) = 86 * xassum06v / .86
mtreff(10) = 86 * xassum06v / .86
mtreff(11) = 86 * xassum06v / .86
mtreff(12) = 86 * xassum06v / .86
mtreff(13) = 86 * xassum06v / .86
mtreff(14) = 86 * xassum06v / .86
mtreff(15) = 86 * xassum06v / .86
mtreff(16) = 86 * xassum06v / .86
mtreff(17) = 86 * xassum06v / .86
mtreff(18) = 84 * xassum06v / .86
mtreff(19) = 84 * xassum06v / .86
mtreff(20) = 82 * xassum06v / .86
mtreff(21) = 81 * xassum06v / .86
mtreff(22) = 80 * xassum06v / .86
mtreff(23) = 78 * xassum06v / .86
mtreff(24) = 75 * xassum06v / .86

asdeff(1) = 89
asdeff(2) = 89
asdeff(3) = 89
asdeff(4) = 89
asdeff(5) = 88
asdeff(6) = 89
```

```
asdeff(7) = 91
asdeff(8) = 93
asdeff(9) = 95
asdeff(10) = 96
asdeff(11) = 96
asdeff(12) = 96
asdeff(13) = 96
asdeff(14) = 96
asdeff(15) = 96
asdeff(16) = 96
asdeff(17) = 95
asdeff(18) = 94
asdeff(19) = 92
asdeff(20) = 91
asdeff(21) = 91
asdeff(22) = 91
asdeff(23) = 90
asdeff(24) = 90

mwh = 0
asdmwh = 0

FOR count = 1 to 24

mwh = mwh + ( -1.23288 + 0.001055 * ( perflow(count) / 100 ) ;
 * xassum09v ) / xassum06v * xassum08v * ( pertime(count) / 100 ) ;
 * xassum03v /1000000

asdmwh = asdmwh + ( -8.59041 + 0.001502 * ( perflow(count) / 100 ) ;
 * xassum09v) / ( mtreff(count) / 100 ) * ( asdeff(count) / 100 ) ;
 * xassum08v * ( pertime(count) / 100 ) * xassum03v / 1000000

ENDFOR

savemwh = mwh - asdmwh

********** calculate number of ECO units **********

* numecouni start

if xaclogtst = 0
    replace numecouni ;
            with ( ( xtraare + xhosmedare + xadmare + xbarare + ;
        xcomfacare ) / xassum01v ) * xassum02v ;
        * ( 1 - penfac )
else
    replace numecouni ;
            with ( ( xtraare + xhosmedare + xadmare + xbarare + ;
        xcomfacare ) / xassum10v ) * xassum02v ;
        * ( 1 - penfac )
endif
```

```
* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with ( numecouni * savemwh * 3.412 )

* eleenesav end

********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with  0

* basdemsav end
```

```
******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

**** Calculate Lbs. of CFCs displaced *****

* cfcdisp start

replace cfcdisp ;
   with 0
```

```
* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Assumptions file (1-10 HP).

```
REEP ECO REPORT                                              Page
1
09/01/94

ECO:  Ventln Motor ASD (Small)

FIELD       DESCRIPTION                                        VALUE
--------------------------------------------------------------------
ECO         Energy Opportunity               Ventln Motor ASD (Small)
UNIT        Unit                                               Motors
ECOTYPE     Energy Opportunity Type                        Electrical
PROGRAM     Rules File (Program) Name                        adjuspes
CAPCOST     Capital Cost                                      1800.00
RECURCOST   Recurring Cost                                       1.00
ECONLIFE    Economic Life                                          00
DISCQTY     Discount Quantity                                   20.00
ASSUM01     ECO Assumption 01             KSer ASD for Installations w
ASSUM01V    ECO Assumption 01 Value                              1.80
ASSUM02     ECO Assumption 02                    % of ASD applications
ASSUM02V    ECO Assumption 02 Value                                 0
```

ASSUM03	ECO Assumption 03	Annual hours of operation
ASSUM03V	ECO Assumption 03 Value	4680.00
ASSUM04	ECO Assumption 04	HVAC cooling energy credit
ASSUM04V	ECO Assumption 04 Value	0.00
ASSUM05	ECO Assumption 05	HVAC cooling energy demand
ASSUM05V	ECO Assumption 05 Value	0.00
ASSUM06	ECO Assumption 06	Existing motor efficiency
ASSUM06V	ECO Assumption 06 Value	0.83
ASSUM07	ECO Assumption 07	AVG HP for range
ASSUM07V	ECO Assumption 07 Value	5.00
ASSUM08	ECO Assumption 08	W/HP
ASSUM08V	ECO Assumption 08 Valu	746.00
ASSUM09	ECO Assumption 09	VIV System Flow CFM
ASSUM09V	ECO Assumption 09 Value	7000.00
ASSUM10	ECO Assumption 10	KSF per ASD for Installations w
ASSUM10V	ECO Assumption 10 Value	6.94

Rules file (1-10 HP).

```
* This is the adjuspes.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

dimension perflow(24)
dimension pertime(24)
dimension mtreff(24)
dimension asdeff(24)

perflow(1) = 53
perflow(2) = 53
perflow(3) = 52
perflow(4) = 50
perflow(5) = 48
perflow(6) = 52
perflow(7) = 63
perflow(8) = 77
perflow(9) = 91
perflow(10) = 97
perflow(11) = 97
perflow(12) = 95
perflow(13) = 95
perflow(14) = 98
perflow(15) = 100
perflow(16) = 97
perflow(17) = 88
perflow(18) = 78
perflow(19) = 70
```

```
perflow(20) = 66
perflow(21) = 65
perflow(22) = 63
perflow(23) = 60
perflow(24) = 56

pertime(1) = 5
pertime(2) = 5
pertime(3) = 4
pertime(4) = 4
pertime(5) = 4
pertime(6) = 4
pertime(7) = 4
pertime(8) = 4
pertime(9) = 4
pertime(10) = 4
pertime(11) = 4
pertime(12) = 4
pertime(13) = 4
pertime(14) = 4
pertime(15) = 4
pertime(16) = 4
pertime(17) = 4
pertime(18) = 4
pertime(19) = 4
pertime(20) = 4
pertime(21) = 4
pertime(22) = 4
pertime(23) = 5
pertime(24) = 5

mtreff(1) = 73 * xassum06v / .86
mtreff(2) = 73 * xassum06v / .86
mtreff(3) = 73 * xassum06v / .86
mtreff(4) = 71 * xassum06v / .86
mtreff(5) = 70 * xassum06v / .86
mtreff(6) = 73 * xassum06v / .86
mtreff(7) = 80 * xassum06v / .86
mtreff(8) = 84 * xassum06v / .86
mtreff(9) = 86 * xassum06v / .86
mtreff(10) = 86 * xassum06v / .86
mtreff(11) = 86 * xassum06v / .86
mtreff(12) = 86 * xassum06v / .86
mtreff(13) = 86 * xassum06v / .86
mtreff(14) = 86 * xassum06v / .86
mtreff(15) = 86 * xassum06v / .86
mtreff(16) = 86 * xassum06v / .86
mtreff(17) = 86 * xassum06v / .86
mtreff(18) = 84 * xassum06v / .86
mtreff(19) = 84 * xassum06v / .86
mtreff(20) = 82 * xassum06v / .86
```

```
mtreff(21) = 81 * xassum06v / .86
mtreff(22) = 80 * xassum06v / .86
mtreff(23) = 78 * xassum06v / .86
mtreff(24) = 75 * xassum06v / .86

asdeff(1) = 89
asdeff(2) = 89
asdeff(3) = 89
asdeff(4) = 88
asdeff(5) = 88
asdeff(6) = 89
asdeff(7) = 91
asdeff(8) = 93
asdeff(9) = 95
asdeff(10) = 96
asdeff(11) = 96
asdeff(12) = 96
asdeff(13) = 96
asdeff(14) = 96
asdeff(15) = 96
asdeff(16) = 96
asdeff(17) = 95
asdeff(18) = 94
asdeff(19) = 92
asdeff(20) = 91
asdeff(21) = 91
asdeff(22) = 91
asdeff(23) = 90
asdeff(24) = 90

mwh = 0
asdmwh = 0

FOR count = 1 to 24

mwh = mwh + ( -.13889 + 0.000705 * ( perflow(count) / 100 ) ;
 * xassum09v ) / xassum06v * xassum08v * ( pertime(count) / 100 ) ;
 * xassum03v /1000000

asdmwh = asdmwh + ( -3.3375 + 0.001131 * ( perflow(count) / 100 ) ;
 * xassum09v ) / ( mtreff(count) / 100 ) * ( asdeff(count) / 100 ) ;
 * xassum08v * ( pertime(count) / 100 ) * xassum03v / 1000000

ENDFOR

savemwh = mwh - asdmwh

********** calculate number of ECO units **********

* numecouni start
```

```
if xaclogtst = 0
    replace numecouni ;
            with ( ( xtraare + xhosmedare + xadmare + xbarare + ;
        xcomfacare ) / xassum01v ) * xassum02v ;
        * ( 1 - penfac )
else
    replace numecouni ;
            with ( ( xtraare + xhosmedare + xadmare + xbarare + ;
        xcomfacare ) / xassum10v ) * xassum02v ;
        * ( 1 - penfac )
endif

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with ( numecouni * savemwh * 3.412 )
```

```
* eleenesav end

********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with  0

* basdemsav end

******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start
```

```
replace watvolsav ;
   with 0

* watvolsav end

***** Calculate Lbs. of CFCs displaced *****

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Envelope

The envelope ECOs in the REEP model target additional insulation for walls and ceilings, and mitigating energy flow through glazed surfaces. The three primary drivers that influence whether an envelope retrofit will pay back rapidly are: climate, cost of energy, and cost of the retrofit. Since most envelope retrofits are an expensive

proposition, and the military generally negotiates low utility rates, most modifications to a building envelope do not have rapid payback periods.

One aspect of envelope retrofits that cannot be quantified and included in the cost/benefit analysis is the impact they have on various aspects of occupant comfort. For example, additional insulation can alter mean radiant temperature characteristics of the envelope and contribute to a greater feeling of thermal comfort; window film or shading devices may decrease glare and increase visual comfort. These benefits may actually result in increased worker productivity and the well being of building occupants, but only the energy savings aspects of the ECOs weigh into the economic evaluation.

6.5 in. of Additional Ceiling Insulation

Background. Many older administrative and training facilities have ceiling and roof assemblies with marginal amounts of insulation. In many instances, it is easy to add additional insulation by simply installing fiberglass batt insulation on top of suspended ceiling tiles. The benefit of installing insulation on top of ceiling tiles rather than on the exterior of the roof is that the space between the ceiling tiles and roof assembly is not heated as it would be if the insulation were installed on the exterior.

Ceiling insulation characteristics. This ECO places 6.5 in. of fiberglass batt insulation with an R-value of 19 on top of suspended ceiling tiles. As with the blown-in insulation for family housing, the appeal of this ECO is that no recurring costs and maintenance requirements are associated with it.

Facility assumptions. This ECO is applied to only 50 percent of all administrative and training type facilities. It is assumed that the remaining 50 percent is adequately insulated and does not require additional insulation. This analysis only accounts for the reduced thermal flux across the ceiling and roof assembly and does not take any credit for reduced infiltration.

Ceiling insulation conclusions. Payback periods for additional ceiling insulation vary considerably. Variance is primarily due to climatic influence. Installations with high heating degree days tend to pay back quicker than installations that are dominated by cooling requirements.

Assumptions file.

```
REEP ECO REPORT                                                    Page  1
07/08/94

ECO:  6.5 Inch Addtnl Clg Insul

FIELD       DESCRIPTION                                              VALUE
--------------------------------------------------------------------------
ECO         Energy Opportunity                  6.5 Inch Addtnl Clg Insul
UNIT        Unit                                                  Sq. Ft.
ECOTYPE     Energy Opportunity Type                              Envelope
PROGRAM     Rules File (Program) Name                            65ceilin
CAPCOST     Capital Cost                                             0.55
RECURCOST   Recurring Cost                                           0.00
ECONLIFE    Economic Life                                           20.00
DISCQTY     Discount Quantity                                    15000.00
ASSUM01     ECO Assumption 01                % of Applicable facility space
ASSUM01V    ECO Assumption 01 Value                                 50.00
ASSUM02     ECO Assumption 02                              kW/ton cooling
ASSUM02V    ECO Assumption 02 Value                                  0.75
ASSUM03     ECO Assumption 03                                     A/C COP
ASSUM03V    ECO Assumption 03 Value                                  2.20
ASSUM04     ECO Assumption 04                Summer Interior Design Temp (F)
ASSUM04V    ECO Assumption 04 Value                                 78.00
ASSUM05     ECO Assumption 05                               Delta U-Value
ASSUM05V    ECO Assumption 05 Value                                  0.13
ASSUM06     ECO Assumption 06                   Original Demand Diversity
ASSUM06V    ECO Assumption 06 Value                                  0.98
ASSUM07     ECO Assumption 07                   Retrofit Demand Diversity
ASSUM07V    ECO Assumption 07 Value                                  0.96
```

Rules file.

```
* This is the 65ceilin.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with ( xtraare + xadmare ) * 1000 * ( xassum01v ;
      / 100 ) * ( 1 - penfac )
```

```
* numecouni end

********* Select Project Size Factor **************

do comcalc0

********** calculate adjusted initial cost **********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * xhdd * 24 * xassum05v / 1000000

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with numecouni * xcdd * 24 * xassum05v / 1000000

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav / xassum03v

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0
```

```
* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
 with numecouni * xassum05v * ( xsumdestem - xassum04v ;
        ) / 12000 * xassum02v * ( xassum06v - xassum07v )

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) * xgascomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) * xoilcomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end
```

```
********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) * xcoacomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end
```

```
********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

*   SECTION  3  -  ECO  specific  calculations  that  override  common
calculations
```

Exterior Insulation Finish System

Background. Exterior Insulation Finish System (EIFS) is a popular envelope retrofit option. The most common form of EIFS is an application of extruded polystyrene insulation fastened or adhered to the exterior of a building, with a stucco-type finish applied over it. This type of building retrofit increases the insulation value of the wall, reduces infiltration through the envelope, and usually improves the appearance of a facility. Although reduced infiltration could substantially contribute to energy savings, no credit for this has been taken for this additional benefit because of the difficulty of quantification and variability from one building to another.

EIFS characteristics.

EIFS cost per square foot:	$ 5.69 (Means Repair and Remodeling Cost Data 1993)
Recurring Cost (%):	5

This cost is for the maintenance of the stucco finish system. The exterior coating occasionally needs cleaning, patching, and repainting.

EIFS R-Value:	5

One common application of EIFS employs 1 in. extruded polystyrene insulation with a stucco finish. The R-value of five reflects the insulation value of the insulation itself and does not take any credit for the stucco finish.

Facility assumptions. EIFS has been analyzed as being applicable to a certain percentage of administrative, community, training, and, barracks-type facilities. The following facility assumptions indicate how each facility type was characterized.

Admin Bldgs.		Comm. Serv.	
Typical building size	6500 sq ft	Typical building size	10200 sq ft
Opaque wall SA/floor SA ratio	0.434	Opaque wall SA/floor SA ratio	0.444
Average wall U-value	0.2	Average wall U-value	0.2
% of total admin space applicable	40	% of total community space applicable	20

Barracks		Training Fac.	
Typical building size	45600 sq ft	Typical building size	4500 sq ft
Opaque wall SA/floor SA ratio	0.284	Opaque wall SA/floor SA ratio	0.648
Average wall U-value	0.2	Average wall U-value	0.2
% of total barracks space applicable	30	% of total training space applicable	40

All typical building sizes were determined using data from Fort Hood, Texas. Typical building size square footage values were calculated by dividing the total square footage of each building category by the number of buildings in that category, and then rounding the value to the nearest 100 sq ft.

The opaque wall surface area to floor surface area ratio is based on numerous assumptions. The following example illustrates the derivation of this value for an administrative type facility.

Assumption 1: Establish a typical footprint for the facility type:
50 ft x 130 ft = 6,500 sq ft

Assumption 2: Exterior wall height = 9 ft 0 in
Calculate exterior wall surface area = 9 ft x (2 x 50 ft + 2 x 130 ft) = 3,240 sq ft

Assumption 3: 13 percent of wall area is doors, windows, and others.

Therefore, Opaque wall surface area = (1 - 0.13) x 3,240 sq ft = 2,819 sq ft
Calculate wall SA to floor SA ratio: 2819 sq ft ÷ 6500 sq ft = 0.434 wall SA / floor SA

Wall SA to floor SA ratios were calculated similarly for the other building types.

At the present time, all existing walls were assumed to have a R-Value of 5. This may appear rather low, but the logic was that the EIFS would probably only be applied to older facilities which typically have very low R-Values. Since it was assumed that EIFS would only be applicable to a certain percentage of the total number of buildings in each group, a percentage factor was included in each facility type characterization.

EIFS conclusions. Justification of an EIFS retrofit will more than likely not be based on simple payback. REEP simple payback periods are generally very long. However, if envelope modifications are being considered regardless of energy retrofit concerns, the energy savings of the EIFS is a nice benefit. The long payback periods are a result of the high capital costs associated with this retrofit.

Assumptions file.

REEP ECO REPORT Page 1
09/01/94

ECO: Ext Insul Finish Sys

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	Ext Insul Finish Sys
UNIT	Unit	Sq. Ft.
ECOTYPE	Energy Opportunity Type	Envelope
PROGRAM	Rules File (Program) Name	exteinsu
CAPCOST	Capital Cost	5.69
RECURCOST	Recurring Cost	5.00
ECONLIFE	Economic Life	20.00
DISCQTY	Discount Quantity	50000.00
ASSUM01	ECO Assumption 01	Admin-Opaque wall SA/floor SA
ASSUM01V	ECO Assumption 01 Value	0.43
ASSUM02	ECO Assumption 02	% of Admin-Applicable space
ASSUM02V	ECO Assumption 02 Value	40.00
ASSUM03	ECO Assumption 03	AC/COP
ASSUM03V	ECO Assumption 03 Value	2.20
ASSUM04	ECO Assumption 04	kW/ton cooling
ASSUM04V	ECO Assumption 04 Value	0.75
ASSUM05	ECO Assumption 05	Original Demand Diversity
ASSUM05V	ECO Assumption 05 Value	0.98
ASSUM06	ECO Assumption 06	Retrofit Demand Diversity
ASSUM06V	ECO Assumption 06 Value	0.96
ASSUM07	ECO Assumption 07	
ASSUM07V	ECO Assumption 07 Value	0.00
ASSUM08	ECO Assumption 08	Summer interior design temp (F)
ASSUM08V	ECO Assumption 08 Value	78.00
ASSUM09	ECO Assumption 09	Delta U-value
ASSUM09V	ECO Assumption 09 Value	0.10
ASSUM10	ECO Assumption 10	Barracks-Opaq wall SA/floor SA
ASSUM10V	ECO Assumption 10 Value	0.28
ASSUM11	ECO Assumption 11	% of Barracks-Applicable space
ASSUM11V	ECO Assumption 11 Value	30.00
ASSUM12	ECO Assumption 12	Comm.Fac-Opaq wall SA/floor SA
ASSUM12V	ECO Assumption 12 Value	0.44
ASSUM13	ECO Assumption 13	% of Comm.Fac-Applicable space
ASSUM13V	ECO Assumption 13 Value	20.00

ASSUM14	ECO Assumption 14	Training-Opaq wall SA/floor SA
ASSUM14V	ECO Assumption 14 Value	0.06
ASSUM15	ECO Assumption 15	% of Training-Applicable space
ASSUM15V	ECO Assumption 15 Value	40.00

Rules file.

```
* This is the exteinsu.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with xadmare * 1000 * xassum01v * ( xassum02v / 100 ;
        ) + xbarare * 1000 * xassum10v * ( xassum11v / ;
        100 ) + xcomfacare * 1000 * xassum12v * ( ;
        xassum13v / 100 ) + xtraare * 1000 * xassum14v ;
        * ( xassum15v / 100) * ( 1 - penfac )

* numecouni end

********* Select Project Size Factor **************

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with xlocind * numecouni * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved ***********

* heaenesav start

replace heaenesav ;
   with numecouni * xhdd * 24 * xassum09v / 1000000

* heaenesav end

********** calculate cooling energy saved **********
```

```
* cooenesav start

replace cooenesav ;
   with numecouni * xcdd * 24 * xassum09v / 1000000

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav / xassum03v

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
   with numecouni * xassum09v * ( xsumdestem - xassum08v ;
        ) / 12000 * xassum04v * ( xassum05v - xassum06v )

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) * xgascomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xgascomeff / 100 )
endif
```

```
* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) * xoilcomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) * xcoacomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start
```

```
replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

6.0 in. of Additional Ceiling Insulation in Family Housing

Background. A portion of family housing units on Army facilities contain inadequate ceiling insulation. A solution is the installation of fiberglass batts above the ceiling assembly to increase the R-value.

Ceiling insulation characteristics. The algorithms assume that 6 in.-thick fiberglass batt insulation of R-value = 19 will be installed above the ceilings of family housing units containing inadequate insulation. It is also assumed that the average R-value of the existing ceiling insulation is 10 (from the unpublished report *Evaluation of Energy Conservation Opportunities in Family Housing Buildings at Fort Hood, Texas* by Architectural Energy Corporation, 30 June 1993).

Facility assumptions. This ECO is applied to only 40 percent of all family housing facilities. The remaining 60 percent contain either adequately insulated ceilings or

construction that prevents installation of this ECO. It is assumed that the average area of a family housing unit is 1500 sq ft.

Ceiling insulation conclusions. The installation of additional ceiling insulation in family housing units pays off well in locations that experience extremes in both summer and winter seasons. Savings produced in locations with a single extreme season or year-round mild weather are generally inadequate to provide a desirable payback period. Some variations in this trend are caused by differences in local energy and demand prices.

Assumptions file.

```
REEP ECO REPORT                                                Page 1
09/01/94

ECO:  FH 6.0 Inch Addtnl Clg Insul

FIELD       DESCRIPTION                                          VALUE
----------------------------------------------------------------------
ECO         Energy Opportunity             FH 6.0 Inch Addtnl Clg Insul
UNIT        Unit                                                Sq. Ft.
ECOTYPE     Energy Opportunity Type                            Envelope
PROGRAM     Rules File (Program) Name                          6ceilgfh
CAPCOST     Capital Cost                                           0.70
RECURCOST   Recurring Cost                                         0.00
ECONLIFE    Economic Life                                         20.00
DISCQTY     Discount Quantity                                  10000.00
ASSUM01     ECO Assumption 01              % of applicable family housing
ASSUM01V    ECO Assumption 01 Value                               40.00
ASSUM02     ECO Assumption 02                           KW / ton cooling
ASSUM02V    ECO Assumption 02 Value                                0.75
ASSUM03     ECO Assumption 03                                   A/C COP
ASSUM03V    ECO Assumption 03 Value                                2.20
ASSUM04     ECO Assumption 04                      Gas Plant Efficiency
ASSUM04V    ECO Assumption 04 Value                               70.00
ASSUM05     ECO Assumption 05                      Oil Plant Efficiency
ASSUM05V    ECO Assumption 05 Value                               65.00
ASSUM06     ECO Assumption 06                     Coal plant efficiency
ASSUM06V    ECO Assumption 06 Value                               60.00
ASSUM07     ECO Assumption 07             Summer Interior Design Temp (F)
ASSUM07V    ECO Assumption 07 Value                               78.00
ASSUM08     ECO Assumption 08                             Delta U-Value
ASSUM08V    ECO Assumption 08 Value                                0.07
```

Rules file.

```
* This is the 6ceilgfh.prg program
```

```
* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with xfamhouare * 1000 * ( xassum01v / 100 ) ;
          * ( 1 - penfac )

* numecouni end

**********Select Project Size Factor*************

do comcalc0

**********Calculate adjusted initial cost********

* inicos start

replace inicos ;
 with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * xhdd * 24 * xassum08v / 1000000

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with numecouni * xcdd * 24 * xassum08v / 1000000

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start
```

```
replace eleenesav ;
   with cooenesav / xassum03v

* eleenesav end

*********Calculate baseload demand saved***********

* basdemsav start

replace basdemsav ;
 with 0

* basdemsav end

*********Calculate summer demand saved*************

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end


********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ;
          / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ) ;
          + ( ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ) ;
          + ( ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ) ) ;
          * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start
```

```
zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ;
          / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ) ;
          + ( ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ) ;
          + ( ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ) ) ;
          * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ;
          / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ) ;
          + ( ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ) ;
          + ( ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ) ) ;
          * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end
```

```
**********Calculate Lbs. of CFC's displaced**************

* cfcdisp start

replace cfcdisp ;
 with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end


do comcalc2

*  SECTION  3  -  ECO  specific  calculations  that  override  common
calculations
```

Family Housing Blown-in Insulation

Background. Older residential buildings frequently have uninsulated walls. A common retrofit technique is to blow insulation into wall cavities. This not only helps insulate the walls, but also reduces infiltration heat gains and losses. The evaluation of this ECO only accounts for the reduced thermal transfer through the walls and does not take any credit for reduced infiltration. This ECO is applied to only 40 percent of family housing units at all installations. It is assumed that the other 60 percent of housing was constructed with insulation in the walls, or has already been retrofitted. Existing insulation values of those buildings being retrofitted is estimated to be R-5.

Rockwool insulation characteristics. Rockwool insulation was selected due to its slightly lower cost as compared to cellulose and fiberglass insulation. All three insulations have similar R-values. This ECO assumes that exterior walls were framed with 2 x 4s and can be filled with 3.5 in. of insulation with an R-value of 11. ECOs such as this reduce both heating and cooling requirements, improve occupant comfort, and have no recurring costs and maintenance requirements.

Facility assumptions. Fort Hood data was used to derive facility characteristics for this ECO. Approximately 8.7 million sq ft of family housing exists at Fort Hood in 2,883 buildings, which is about 3,000 sq ft per building. After subtracting for windows, doors, and allowing for framing, the ratio of insulatable wall cavity area to floor area is 0.85.

Family housing wall insulation conclusions. The blown-in rockwool analysis indicates rapid paybacks at most installations. The longer paybacks are primarily at installations that have few heating degree days.

Assumptions file.

```
REEP ECO REPORT                                                Page 1
09/01/94

ECO:  FH Rockwool Wall Insulation

FIELD       DESCRIPTION                                          VALUE
-----------------------------------------------------------------------
ECO          Energy Opportunity             FH Rockwool Wall Insulation
UNIT         Unit                                              Sq. Ft.
ECOTYPE      Energy Opportunity Type                          Envelope
PROGRAM      Rules File (Program) Name                        blowinfh
CAPCOST      Capital Cost                                         0.97
RECURCOST    Recurring Cost                                       0.00
ECONLIFE     Economic Life                                       20.00
DISCQTY      Discount Quantity                                10000.00
ASSUM01      ECO Assumption 01             Opaque wall SA/floor SA ratio
ASSUM01V     ECO Assumption 01 Value                              0.85
ASSUM02      ECO Assumption 02                 % of Applicable FH space
ASSUM02V     ECO Assumption 02 Value                             40.00
ASSUM03      ECO Assumption 03                                 A/C COP
ASSUM03V     ECO Assumption 03 Value                              2.20
ASSUM04      ECO Assumption 04                          kW / ton cooling
ASSUM04V     ECO Assumption 04 Value                              0.75
ASSUM05      ECO Assumption 05           Summer Interior Design Temp (F)
ASSUM05V     ECO Assumption 05 Value                             78.00
ASSUM06      ECO Assumption 06                           Delta U-Value
ASSUM06V     ECO Assumption 06 Value                              0.14
ASSUM07      ECO Assumption 07               Original Demand Diversity
```

```
ASSUM07V    ECO Assumption 07 Value                                  0.98
ASSUM08     ECO Assumption 08                   Retrofit Demand Diversity
ASSUM08V    ECO Assumption 08 Value                                  0.96
```

Rules file.

```
* This is the blowinfh.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with xfamhouare * 1000 * xassum01v * ( xassum02v ;
         / 100 ) * ( 1 - penfac )

* numecouni end

********* Select Project Size Factor **************

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with xlocind * numecouni * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * xhdd * 24 * xassum06v / 1000000

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
```

```
   with numecouni * xcdd * 24 * xassum06v / 1000000

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav / xassum03v

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
 with numecouni * xassum06v * ( xsumdestem - xassum05v ;
       ) / 12000 * xassum04v * ( xassum07v - xassum08v )

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

if xghp75con = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp75con ) * xgascomeff / ((( xghp75con ) * xgascomeff )
+ ;
          (( xohp75con ) * xoilcomeff ) + (( xchp75con ) * xcoacomeff
)) ;
         * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********
```

```
* oilenesav start

if xohp75con = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp75con ) * xoilcomeff / ((( xghp75con ) * xgascomeff )
+ ;
          (( xohp75con ) * xoilcomeff ) + (( xchp75con ) * xcoacomeff
)) ;
          * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

if xchp75con = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp75con ) * xcoacomeff / ((( xghp75con ) * xgascomeff )
+ ;
          (( xohp75con ) * xoilcomeff ) + (( xchp75con ) * xcoacomeff
)) ;
          * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end
```

```
* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved ***********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

High Reflectance Roof Surface

Background. Roof color can influence a buildings energy consumption. In tall multi-story buildings where the square footage of roof surface is small compared to total envelope area, this is not much of an issue. However, most buildings on military installations tend to be small to medium-sized and roof surface area constitutes a large portion of the total envelope surface area. Increasing roof solar reflectance can save cooling energy while increasing heating energy requirements. This ECO models the effect of altering the reflectance characteristics of the roof surface on 30 percent of training, administrative, and family housing buildings. Algorithms for this ECO were taken from a study conducted by Oak Ridge National Laboratory (ORNL) (Griggs, Sharp, and MacDonald, August 1989).

Membrane Characteristics

This ECO assumes a change in roof surface reflectance values due to the installation of a high reflectance roof membrane.

Existing roof reflectance	0.234	(Gravel coated asphalt roof surface)
Replacement roof surface reflectance	0.780	(White Hypalon membrane)
Change in reflectance	0.546	

Facility assumptions. An assumption had to be made regarding the existing R-value of the existing roof system, so it was set at R = 8. The air-conditioning coefficient of performance (COP) was set to 2.2 to match that used in the ORNL study.

Membrane conclusions. At certain installations, the rapid payback of using a high reflective roof surface was rather surprising. Simple paybacks varied from 2 to 227 years. This great variation was due to large differences in the amount of solar radiation at installations, the number of heating and cooling degree days (HDDs/CDDs), and the heating and cooling factors, which are related to HDD and CDD. The costs used for this ECO reflect new construction prices. If a new roof was needed and a high reflectance roof was installed instead of a conventional roof, only a delta cost would need to be considered (since the reflective roofs are slightly more costly) and payback periods would be much shorter than indicated by this analysis.

Assumptions file.

```
REEP ECO REPORT                                              Page  1
07/07/94

ECO:  High Reflctnce Roof Membrn

FIELD        DESCRIPTION                                       VALUE
--------------------------------------------------------------------
ECO          Energy Opportunity             High Reflctnce Roof Membrn
UNIT         Unit                                            Sq. Ft.
ECOTYPE      Energy Opportunity Type                        Envelope
PROGRAM      Rules File (Program) Name                      roofsurf
CAPCOST      Capital Cost                                       3.44
RECURCOST    Recurring Cost                                     0.00
ECONLIFE     Economic Life                                     20.00
DISCQTY      Discount Quantity                              10000.00
ASSUM01      ECO Assumption 01                % of Applicable buildings
ASSUM01V     ECO Assumption 01 Value                           30.00
ASSUM02      ECO Assumption 02           Summer interior design temp (F)
ASSUM02V     ECO Assumption 02 Value                           78.00
ASSUM03      ECO Assumption 03                               A/C COP
ASSUM03V     ECO Assumption 03 Value                            2.20
ASSUM04      ECO Assumption 04                    kW demand savings (%)
ASSUM04V     ECO Assumption 04 Value                           50.00
ASSUM05      ECO Assumption 05                   Change in reflectance
ASSUM05V     ECO Assumption 05 Value                            0.55
ASSUM06      ECO Assumption 06               Equivalent Summer U-Value
ASSUM06V     ECO Assumption 06 Value                            8.00
ASSUM07      ECO Assumption 07                         kW/ton cooling
ASSUM07V     ECO Assumption 07 Value                            0.75
ASSUM08      ECO Assumption 08               Original Demand Diversity
ASSUM08V     ECO Assumption 08 Value                            0.98
```

```
ASSUM09     ECO Assumption 09                 Retrofit Demand Diversity
ASSUM09V    ECO Assumption 09 Value                                0.96
```

Rules file.

```
* This is the roofsurf.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

*********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with ( xtraare + xadmare + xfamhouare ) * 1000 * ( ;
        xassum01v / 100 ) * ( 1 - penfac )

* numecouni end

********* Select Project Size Factor **************

do comcalc0

********** calculate adjusted initial cost **********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with -1 * numecouni * xtotglorad * xassum05v * xheafac ;
        / 1000000

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
```

```
   with numecouni * xtotglorad * xassum05v * xcoofac / ;
        1000000

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav / xassum03v

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
   with numecouni * xassum06v * ( xsumdestem - xassum02v ) ;
   * xassum07v * xassum04v / 1200000 * ( xassum08v ;
   - xassum09v )

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) * xgascomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xgascomeff / 100 )
endif
```

```
* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) * xoilcomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) * xcoacomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********
```

```
* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Radiant Barriers

Background. Heat can be transferred through the building envelope via conduction, convection, and radiation. Insulation and thermal breaks mitigate conduction and convection losses and gains; however, heat transfer through radiation is largely ignored. Radiant barriers provide the means to practically eliminate far-infrared radiation from entering a building. Eliminating this component of heat gain can result in a measurable reduction in air-conditioning loads. Radiant barriers should primarily be used in envelope dominated buildings such as housing and other smaller administration-type buildings. They can also be used in warehouses and maintenance facilities to improve comfort conditions. Radiant barriers have their greatest effect during the cooling season and thus are evaluated only at installations with warmer climates.

Radiant barrier characteristics. Radiant barriers can be incorporated as an integral part of the ceiling structure, or be retrofitted into an attic space. Radiant barriers can be evaluated as having an "equivalent" R or U-value, which is how this ECO analysis was conducted.

Facility assumptions. This ECO applies only to family housing, small administration, and training facilities in climates with more than 1500 CDDs. This ECO assumes that only 30 percent of all of the building types considered are potential candidates for radiant barriers. The other 70 percent either have sufficient insulation so that radiant barriers would be lesss effective or have other conditions that preclude the use of a radiant barrier system.

Radiant barrier conclusion. Radiant barriers unquestionably can save energy, but their payback effectiveness depends on installed cost per square foot. The cost used for this analysis is for a spray-applied coating to the roof surface. Spray-applied coating is probably the easiest type of retrofit radiant barrier system available for existing construction and has the additional benefit of reduced thermal cycling of the roof surface itself, thus extending its life expectancy.

Assumptions file.

```
REEP ECO REPORT                                                 Page  1
07/07/94

ECO:  Radiant Barriers

FIELD       DESCRIPTION                                           VALUE
----------------------------------------------------------------------
ECO         Energy Opportunity                         Radiant Barriers
UNIT        Unit                                               Sq. Ft.
ECOTYPE     Energy Opportunity Type                           Envelope
PROGRAM     Rules File (Program) Name                         radibarr
CAPCOST     Capital Cost                                          0.34
RECURCOST   Recurring Cost                                        0.00
ECONLIFE    Economic Life                                        20.00
DISCQTY     Discount Quantity                                 10000.00
ASSUM01     ECO Assumption 01                  % of Applicable buildings
ASSUM01V    ECO Assumption 01 Value                              30.00
ASSUM02     ECO Assumption 02             Summer interior design temp (F)
ASSUM02V    ECO Assumption 02 Value                              78.00
ASSUM03     ECO Assumption 03                                  A/C COP
ASSUM03V    ECO Assumption 03 Value                               2.20
ASSUM04     ECO Assumption 04                              CDD cut-off
ASSUM04V    ECO Assumption 04 Value                            1500.00
ASSUM05     ECO Assumption 05                          kW/ton cooling
ASSUM05V    ECO Assumption 05 Value                               0.75
```

ASSUM06	ECO Assumption 06	Summer Delta U-Value
ASSUM06V	ECO Assumption 06 Value	0.07
ASSUM07	ECO Assumption 07	Winter Delta U-Value
ASSUM07V	ECO Assumption 07 Value	0.03
ASSUM08	ECO Assumption 08	Original Demand Diversity
ASSUM08V	ECO Assumption 08 Value	0.98
ASSUM09	ECO Assumption 09	Retrofit Demand Diversity
ASSUM09V	ECO Assumption 09 Value	0.96

Rules file.

```
* This is the radibarr.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xcdd > xassum04v
      replace numecouni ;
         with ( xtraare + xadmare + xfamhouare ) * 1000 * ;
              ( xassum01v / 100 ) * ( 1 - penfac )
else
      replace numecouni ;
         with 0
endif

* numecouni end

********* Select Project Size Factor **************

do comcalc0

********** calculate adjusted initial cost **********

* inicos start

replace inicos ;
   with xlocind * numecouni * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start
```

```
replace heaenesav ;
   with numecouni * xhdd * 24 * xassum07v / 1000000

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with numecouni * xcdd * 24 * xassum06v / 1000000

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav / xassum03v

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
 with numecouni * xassum06v * ( xsumdestem - xassum02v ;
        ) / 12000 * xassum05v * (xassum08v - xassum09v )

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
```

```
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) * xgascomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) * xoilcomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) * xcoacomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start
```

```
replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Shading Devices

Background. "The most effective way to reduce the solar load on fenestration is to intercept direct radiation from the sun before it reaches the glass. Windows fully shaded from the outside reduce solar heat gain as much as 80%" (Parsons 1989). The shading device ECO models the installation of solar shade screens over glazed areas on the East, West, and Southern elevation. These screens mount on the exterior of glazed surfaces. Visibility through the screens is unimpaired, while the reduced

brightness ratio between the window and its surroundings can improve interior illumination ratios.

Shading characteristics. Solar shade screens are evaluated only for their ability to reduce air-conditioning loads. Their effect on energy consumption during the heating season is negligible. Table D3 provides the heat gain values on various elevations at different latitudes used to evaluate the shade screens. These values are from a previous study conducted for USAEHSC (Robert Nemeth, USACERL, Champaign, IL, unpublished report, *Energy Conservation of Louvered SunScreens to EHSA for Task Order No. 0031*, 5 August 1991). Installations at 36 degrees latitude or less use the values for 32 degrees latitude, and installations between 36 and 44 degrees latitude use the values from 40 degrees latitude. Anything above 44 degrees latitude is not considered.

Facility assumptions. The shading device ECO applies only to family housing, small administrative, and training type facilities. This ECO assumes that only 40 percent of all of the building types considered are potential candidates for shade screens. The other 60 percent either have shading from other sources such as trees and overhangs or have other conditions that preclude the use of solar shading screens. Furthermore, it is assumed that glazing is evenly distributed on all four elevations.

Typical Building Size (sq ft):	6,500
Applicable Buildings (%):	40
Summer Interior Design Temperature (°F):	78
A/C COP:	2.2
CDD Cutoff:	1500
kW/Ton Cooling (kW/ton):	0.75

Table D3. Shade screen heat gain values.

Latitude	Btu/SF/Yr Elevation	Btu/SF/Yr Existing Glazing	Btu/SF/Yr SSS Retrofit	Btu/SF/Hr Difference	Hrly Gain @ 10:00
32	South	179085	34151	144934	141
32	East/West	209111	40394	168717	154
40	South	109741	19976	89765	165
40	East/West	132466	24412	108054	148

Reduction in Peak Gain - 60 percent.

Shading conclusion. In the right situation, shading screens can significantly reduce air-conditioning loads and improve interior lighting conditions. Their payback effectiveness depends highly on four parameters: (1) location (i.e., latitude), (2) fenestration orientation, (3) installed cost, and (4) cost of energy. Unfortunately some of the additional benefits gained from shade screen installation are unquantifiable and cannot be included in the payback analysis.

Assumptions file.

```
REEP ECO REPORT                                                Page 1
09/01/94

ECO:  Shading Devices
FIELD      DESCRIPTION                                          VALUE
---------------------------------------------------------------------
ECO        Energy Opportunity                        Shading Devices
UNIT       Unit                                             Sq. Ft.
ECOTYPE    Energy Opportunity Type                         Envelope
PROGRAM    Rules File (Program) Name                       shadscre
CAPCOST    Capital Cost                                       10.00
RECURCOST  Recurring Cost                                      0.00
ECONLIFE   Economic Life                                      20.00
DISCQTY    Discount Quantity                                2000.00
ASSUM01    ECO Assumption 01                 Glazed SA/floor SA ratio
ASSUM01V   ECO Assumption 01 Value                             0.06
ASSUM02    ECO Assumption 02                         kW/cooling ton
ASSUM02V   ECO Assumption 02 Value                             0.75
ASSUM03    ECO Assumption 03           % of Applicable building space
ASSUM03V   ECO Assumption 03 Value                            40.00
ASSUM04    ECO Assumption 04                     HVAC energy savings
ASSUM04V   ECO Assumption 04 Value                            10.00
ASSUM05    ECO Assumption 05                     HVAC demand savings
ASSUM05V   ECO Assumption 05 Value                             5.00
ASSUM06    ECO Assumption 06                                A/C COP
ASSUM06V   ECO Assumption 06 Value                             3.00
ASSUM07    ECO Assumption 07               Original Demand Diversity
ASSUM07V   ECO Assumption 07 Value                             0.98
ASSUM08    ECO Assumption 08               Retrofit Demand Diversity
ASSUM08V   ECO Assumption 08 Value                             0.96
ASSUM09    ECO Assumption 09
ASSUM09V   ECO Assumption 09 Value                             0.00
ASSUM10    ECO Assumption 10          Summer interior design temp (F)
ASSUM10V   ECO Assumption 10 Value                            78.00
ASSUM11    ECO Assumption 11                 Reduction in peak gain
ASSUM11V   ECO Assumption 11 Value                            60.00
ASSUM12    ECO Assumption 12                    32 S Btu/sf/yr diff
ASSUM12V   ECO Assumption 12 Value                        144934.00
ASSUM13    ECO Assumption 13                  32 E/W Btu/sf/yr diff
ASSUM13V   ECO Assumption 13 Value                        168717.00
```

ASSUM14	ECO Assumption 14	40 S Btu/sf/yr diff
ASSUM14V	ECO Assumption 14 Value	89765.00
ASSUM15	ECO Assumption 15	40 E/W Btu/sf/yr diff
ASSUM15V	ECO Assumption 15 Value	108054.00
ASSUM16	ECO Assumption 16	32 S Btu/sf/hr hrly gain 10
ASSUM16V	ECO Assumption 16 Value	141.00
ASSUM17	ECO Assumption 17	32 E/W Btu/sf/hr hrly gain 10
ASSUM17V	ECO Assumption 17 Value	154.00
ASSUM18	ECO Assumption 18	40 S Btu/sf/hr hrly gain 10
ASSUM18V	ECO Assumption 18 Value	165.00
ASSUM19	ECO Assumption 19	40 E/W Btu/sf/hr hrly gain 10
ASSUM19V	ECO Assumption 19 Value	148.00

Rules file.

```
* This is the shadscre.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with ( xtraare + xadmare + xbarare ) * 1000 * ;
        xassum01v * (xassum03v / 100 ) * ( 1 - penfac )

* numecouni end

********* Select Project Size Factor **************

do comcalc0

********** calculate adjusted initial cost **********

* inicos start

replace inicos ;
   with xlocind * numecouni * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start
```

```
replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

if    xlatdeg < 36
      replace cooenesav ;
         with ( 0.25 * numecouni * xassum12v + 0.50 * ;
              numecouni * xassum13v )  / 1000000
else
      if  xlatdeg < 44
            replace cooenesav ;
               with ( 0.25 * numecouni * xassum14v + 0.50 * ;
                    numecouni * xassum15v) / 1000000
      else
            replace cooenesav ;
               with 0
      endif
endif

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav / xassum06v

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

if    xlatdeg < 36
```

```
      replace sumdemsav ;
         with ( 0.25 * numecouni * xassum16v + 0.50 * ;
              numecouni * xassum17v ) * ' xassum11v / 100 ;
              ) * xassum02v / 12000 * ( xassum07v - xassum08v )
else
      if  xlatdeg < 44
            replace sumdemsav ;
               with ( 0.25 * numecouni * xassum18v + 0.50 * ;
                    numecouni * xassum19v ) * ( xassum11v / ;
                    100 ) * xassum02v / 12000 * ( xassum07v ;
                     - xassum08v )
      else
            replace sumdemsav ;
               with 0
      endif
endif

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) * xgascomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) * xoilcomeff / ;
```

```
        ((( xghp35con + xghp7535con + xghp75con ) * xgasscomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) * xcoacomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********
```

```
* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with elecossav * xassum04v / 100

* henecossav end

do comcalc2

*  SECTION  3  -  ECO  specific  calculations  that  override  common
calculations
```

Storm Windows

Background. Storm windows are installed to reduce thermal transmission and infiltration rates across existing window units. Cost of storm window units can vary considerably depending on the quality of the unit, size, and its location (i.e., first floor or above).

Storm window characteristics. Storm windows are a rather expensive ECO. This analysis assumes that no envelope or window frame modifications need to be made to accept the storm windows.

Facility assumptions. Buildings for this ECO were characterized as being 55 ft x 100 ft (5,500 sq ft). Exterior walls were set at 10 ft high with 10 percent of the surface area glazed for a total glazed area of 310 sq ft per building. Existing windows were presumed to be single pane. This ECO was applied to 40 percent of all administrative, training, and barracks facilities.

Storm window conclusions. Due to the high cost of storm windows, payback periods are usually very long. This analysis did not take any credit for reduced infiltration, which would help shorten payback periods. Thus, this estimate is rather conservative. One problem with this ECO is that storm windows frequently are not used as they should be and consequently do not save energy as intended.

Assumptions file.

```
REEP ECO REPORT                                                  Page 1
09/01/94

ECO:  Storm Windows

FIELD       DESCRIPTION                                           VALUE
-----------------------------------------------------------------------
ECO         Energy Opportunity                              StormWindows
UNIT        Unit                                                 Sq. Ft.
ECOTYPE     Energy Opportunity Type                             Envelope
PROGRAM     Rules File (Program) Name                           storwind
CAPCOST     Capital Cost                                           11.99
RECURCOST   Recurring Cost                                          0.00
ECONLIFE    Economic Life                                          20.00
DISCQTY     Discount Quantity                                     200.00
ASSUM01     ECO Assumption 01                       Glazed SA / floor SA
ASSUM01V    ECO Assumption 01 Value                                 0.06
ASSUM02     ECO Assumption 02                      % of Applicable space
ASSUM02V    ECO Assumption 02 Value                                40.00
ASSUM03     ECO Assumption 03                        HVAC energy savings
ASSUM03V    ECO Assumption 03 Value                                 5.00
ASSUM04     ECO Assumption 04                        HVAC demand savings
ASSUM04V    ECO Assumption 04 Value                                 5.00
ASSUM05     ECO Assumption 05                           kW / ton cooling
ASSUM05V    ECO Assumption 05 Value                                 0.75
ASSUM06     ECO Assumption 06                                    A/C COP
ASSUM06V    ECO Assumption 06 Value                                 2.20
ASSUM07     ECO Assumption 07             Summer Interior Design Temp (F)
ASSUM07V    ECO Assumption 07 Value                                78.00
ASSUM08     ECO Assumption 08                              Delta U-Value
ASSUM08V    ECO Assumption 08 Value                                 0.67
ASSUM09     ECO Assumption 09                Original Demand Diversity
ASSUM09V    ECO Assumption 09 Value                                 0.98
ASSUM10     ECO Assumption 10                Retrofit Demand Diversity
ASSUM10V    ECO Assumption 10 Value                                 0.95
```

Rules file.

```
* This is the storwind.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********
```

```
* numecouni start

replace numecouni ;
   with ( xtraare + xadmare + xbarare ) * 1000 * ;
        xassum01v * ( xassum02v / 100 ) * ( 1 - penfac )

* numecouni end

********* Select Project Size Factor **************

do comcalc0

********** calculate adjusted initial cost **********

* inicos start

replace inicos ;
   with xlocind * numecouni * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * xhdd * 24 * xassum08v / 1000000

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with numecouni * xcdd * 24 * xassum08v / 1000000

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav / xassum06v

* eleenesav end

********** calculate baseload demand saved **********
```

```
* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

if     numecouni * xassum08v * ( xsumdestem - xassum07v ) ;
         / 12000 * xassum05v < 0
       replace sumdemsav ;
          with 0
else
       replace sumdemsav ;
          with numecouni * xassum08v * ( xsumdestem - ;
               xassum07v ) / 12000 * xassum05v * ( xassum09v ;
                - xassum10v )
endif

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) * xgascomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
```

```
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) * xoilcomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) * xcoacomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end
```

```
* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with elecossav * ( xassum03v / 100 )

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Window Films

Background. In the same vein as storm windows, another means to reduce energy transmission through glazing systems is though the application of window films. Window films will not help reduce infiltration as storm windows do, but transfer of radiant energy through glazing can be greatly reduced. Furthermore, films can be installed from the interior of buildings and are far less expensive than storm windows. Window films can also be used to reduce glare where too much sunlight enters a workspace.

Facility assumptions. The window films ECO applies only to family housing, small administration, and training type facilities. This ECO assumes that only 40 percent of the building types considered are potential candidates for window films. The other 60 percent either have shading from other sources such as trees and overhangs or have other conditions that preclude the use of a window film. Furthermore, it is assumed that glazing is evenly distributed on all four elevations.

Film characteristics. Optical and thermal characteristics can vary greatly with the numerous types of window films available. This ECO assumes that the film increases the R-value of the single pane glazing by a factor of one.

Assumptions file.

```
REEP ECO REPORT                                                Page 1
09/01/94

ECO:  Window Film

FIELD        DESCRIPTION                                       VALUE
--------------------------------------------------------------------
ECO          Energy Opportunity                          Window Film
UNIT         Unit                                            Sq. Ft.
ECOTYPE      Energy Opportunity Type                        Envelope
PROGRAM      Rules File (Program) Name                      windfilm
CAPCOST      Capital Cost                                       1.97
RECURCOST    Recurring Cost                                     0.00
ECONLIFE     Economic Life                                     10.00
DISCQTY      Discount Quantity                              10000.00
ASSUM01      ECO Assumption 01               Glazed SA / floor SA ratio
ASSUM01V     ECO Assumption 01 Value                            0.06
ASSUM02      ECO Assumption 02         % of Applicable bldngs-adm. & t
ASSUM02V     ECO Assumption 02 Value                           40.00
ASSUM03      ECO Assumption 03         Summer Interior Design Temp (F)
ASSUM03V     ECO Assumption 03 Value                           78.00
ASSUM04      ECO Assumption 04                         Delta U-Value
ASSUM04V     ECO Assumption 04 Value                            0.50
ASSUM05      ECO Assumption 05                               A/C COP
ASSUM05V     ECO Assumption 05 Value                            3.00
ASSUM06      ECO Assumption 06         Summer interior design temp (F)
ASSUM06V     ECO Assumption 06 Value                           78.00
ASSUM07      ECO Assumption 07                       kW / ton cooling
ASSUM07V     ECO Assumption 07 Value                            0.75
ASSUM08      ECO Assumption 08             Original Demand Diversity
ASSUM08V     ECO Assumption 08 Value                            0.98
ASSUM09      ECO Assumption 09             Retrofit Demand Diversity
ASSUM09V     ECO Assumption 09 Value                            0.97
```

Rules file.

```
* This is the windfilm.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc
```

```
********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with ( xtraare + xadmare + xbarare ) * 1000 * ;
       xassum01v * ( xassum02v / 100 ) * ( 1 - penfac )

* numecouni end

********* Select Project Size Factor **************

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with xlocind * numecouni * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * xhdd * 24 * xassum04v / 1000000

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with numecouni * xcdd * 24 * xassum04v / 1000000

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav / xassum05v

* eleenesav end
```

```
********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

if numecouni * xassum04v * ( xsumdestem - xassum06v ) ;
     / 12000 * xassum07v < 0
      replace sumdemsav ;
         with 0
else
      replace sumdemsav ;
         with numecouni * xassum04v * ( xsumdestem - ;
              xassum06v ) / 12000 * xassum07v * ( xassum08v ;
              - xassum09v )
endif

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) * xgascomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start
```

```
zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) * xoilcomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) * xcoacomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0
```

```
* cfcdisp end

* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Heating, Ventilating, and Air Conditioning

Heating and cooling systems offer large opportunities for energy conservation. Approaches to energy savings in this area involve the improvement of existing systems, the complete replacement of inefficient systems, heat recovery/rejection in ventilation exhaust streams, and improving the control of existing systems.

Improving the efficiency and control of existing systems costs less money up front and often provides rapid paybacks (less than 5 years). Improving the control of systems is probably the most attractive ECO within this group due to the low investment cost and high returns. Another very attractice ECO is improving the combustion efficiency of oil burners through the installation of flame retention burners. Completely replacing older systems tends to cost more up front, and payback over longer periods (6 to 8 years). However, the payback of this approach greatly decreases if older systems need to be replaced anyway. Ventilation heat recovery/rejection falls somewhere between the two former groups and is highly dependent on local climatic conditions and the physical configuration of the ductwork.

Many of the heating and cooling ECOs pertain to family housing units which are often a significant portion of the building area within an installation. For example, replacing older air-conditioning and furnace units with more efficient units, insulating and sealing ductwork, installing heat pumps, whole-house fans, and programmable thermostats. Some of the most rapid paybacks in family housing are achieved with minimal investment; namely, sealing and insulating ducts and installing programmable thermostats.

Other heating and cooling ECOs apply to larger buildings: new gas and oil boilers, digital HVAC control panels, ventilation heat and enthalpy recovery, and the evaporative precooling of intake air.

Enthalpy Recovery Using a Desiccant Wheel

Background. A desiccant wheel is a rotating heat exchanger capable of transferring both sensible and latent heat and is often installed between the exhaust and makeup air streams. In the winter, incoming low-temperature air is warmed through the exchanger by the warmer exhaust air. In the summer, incoming hot, humid air is cooled and dried by the exhaust air. Thus, a sensible heat savings is accomplished year-round, while a latent heat savings is achieved during the cooling season.

Desiccant wheel characteristics.

Capacity of Wheel	1500	cfm

Facility assumptions. This ECO was applied to percentages of barracks, training, medical, research and development (R&D), community, and administration buildings. It is assumed that ventilation occurred 12 hours per day (except medical) and that the ventilation rate is 100 cfm per thousand feet of building area. It is also assumed that only 30 percent of the locations have the adjacent ductwork (between make-up and exhaust) necessary for the installation of this technology. The rest of the locations are considered for the ventilation heat recovery ECO, which uses a run-around coil as a heat exchanger.

Uncited sources for this section.

Sliwinski, et al., February 1979; Energy Conservation Workshop organized by Facilities Engineering Support Agency, product literature; The Airflow Company product literature on Dehumidification Products.

Assumptions file.

```
REEP ECO REPORT                                                Page 1
07/08/94

ECO:  Enthalpy Recvry Desscnt Wheel

FIELD       DESCRIPTION                                           VALUE
---------------------------------------------------------------------
ECO         Energy Opportunity              Enthalpy Recvry Desscnt Wheel
UNIT        Unit                                                   Wheels
ECOTYPE     Energy Opportunity Type                       Heating/Cooling
PROGRAM     Rules File (Program) Name                           enthalpy
CAPCOST     Capital Cost                                         3300.00
RECURCOST   Recurring Cost                                         20.00
ECONLIFE    Economic Life                                          15.00
DISCQTY     Discount Quantity                                      30.00
ASSUM01     ECO Assumption 01                     Barracks (% applicable)
ASSUM01V    ECO Assumption 01 Value                                33.00
ASSUM02     ECO Assumption 02                     Training (% applicable)
ASSUM02V    ECO Assumption 02 Value                                20.00
ASSUM03     ECO Assumption 03                      Medical (% applicable)
ASSUM03V    ECO Assumption 03 Value                               100.00
ASSUM04     ECO Assumption 04                          R&D (% applicable)
ASSUM04V    ECO Assumption 04 Value                                80.00
ASSUM05     ECO Assumption 05                    Community (% applicable)
ASSUM05V    ECO Assumption 05 Value                                50.00
ASSUM06     ECO Assumption 06               Administration (% applicable)
ASSUM06V    ECO Assumption 06 Value                                50.00
ASSUM07     ECO Assumption 07                                      AC COP
ASSUM07V    ECO Assumption 07 Value                                 3.00
ASSUM08     ECO Assumption 08            Efficiency of Sensible Heat Rec
ASSUM08V    ECO Assumption 08 Value                                60.00
ASSUM09     ECO Assumption 09            Efficiency of Latent Heat Recov
ASSUM09V    ECO Assumption 09 Value                                30.00
ASSUM10     ECO Assumption 10            Hours per day of ventilation (e
ASSUM10V    ECO Assumption 10 Value                                12.00
ASSUM11     ECO Assumption 11            Assumed ventilation rate [cfm/k
ASSUM11V    ECO Assumption 11 Value                               100.00
ASSUM12     ECO Assumption 12            % Locations Applicable (Adjacen
ASSUM12V    ECO Assumption 12 Value                                 0.30
```

Rules file.

```
* This is the ventheat.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********
```

```
do comcalc

********* THIS ANALYSIS IS ADAPTED FROM THE VENTILATION HEAT RECOVERY
ANALYSIS **********
********* calculation of W (absolute humidity ratio) ********
********* to determine the latent heat content of ***********
********* the ventilation air stream, by location.***********
      ********* See ASHRAE Fundamentals 1989 6.13
***************************************

*** calculate atmosheric pressure [psia] based on elevation ***
Patm = 100.000
Patm = ( -0.000486333 * xele ) + 14.696
*** average the mean wet-bulb temps from the 80-84 and 85-89 bins,
convert to Rankine ***
Twb = 100.00
 Twb = ( ( xmcwb8084 + xmcwb8589 ) / 2 ) + 459.67
*** convert the average dry-bulb temp from the 80-84 and 85-89 bins to
Rankine ***
Tdb = 100.00
Tdb = 84.5 + 459.67
*** calculate Pws(t*) [psia] ***
Pwstwb = 1.0000000
Pwstwb = EXP ( ( -10440.39708 / Twb ) - 11.2946496 - ( 0.027022355 *
Twb ) + ; ( 0.00001289036 * Twb^2 ) - ( 0.000000002478068 * Twb^3 ) +
;( 6.5459673 * LOG ( Twb ) ) )
*** calculate Ws* ***
Wswb = 1.0000000
Wswb = ( 0.62189 * ( Pwstwb / ( Patm - Pwstwb ) ) )
*** calculate W  ***
W = 1.0000000
W = ( ( ( 1093 - 0.556 * Twb ) * Wswb - 0.24 * ( Tdb - Twb ) ) / ;
( 1093 + ( 0.444 * Tdb ) - Twb ) )

*******Calculate the sensible heat content of the vent airstream in
[MBtu/day*F*kft2] *************
[MBtu/day*F*Kft2] = [cfm/Kft2] * [min/day] * [Btu/lb*F] * [lb/ft3]
Hdotsens = (xassum11v * (1440) * (.24) * (.075)) / 1000000

*******Calculate the sensible heat content of the vent airstream in
[MBtu/hr*F*kft2] *************
[MBtu/hr*F*Kft2] = [cfm/Kft2] * [min/hr] * [Btu/lb*F] * [lb/ft3]
Hdotsenshr = Hdotsens / 24

*******Calculate the latent heat content of the vent airstream in
[MBtu/hr*F*kft2] *************
[MBtu/hr*F*Kft2] = [cfm/Kft2]air * [min/hr] * [Btu/lb*F]h2o * W *
[lb/ft3]air
Hdotlathr = (xassum11v * (60) * (.445) * W * (.075)) / 1000000

*******Calculate the Unit Demand (Btu/hr*Kft2)*********************
```

```
[Btu/hr*Kft2] = ([cfm/Kft2] * (min/hr) * rhoAir[lb/ft3] *
deltaT[F])*(Cpair[Btu/lbF] + W[lbh20/lbair]*Cph2o)
Udem = (xassum11v * 60 * .075 * 5 * (.24 + (.445 * W)))

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with ( 2 * xassum02v / 100 * xtraare / 22 ) + ( 3 * ;
        xassum04v / 100 * xrdtare / 36 ) + ( xassum03v ;
        / 100 * xhosmedare / 16 ) + ( 1.25 * xassum06v ;
        / 100 * xadmare / 15 ) + ( 3 * xassum01v / 100 ;
        * xbarare / 45.6 ) + ( xassum05v / 100 * ;
        xcomfacare / 10.2 ) * ( 1 - penfac ) * xassum12v

* numecouni end

**********Select Project Size Factor*************

do comcalc0

**********Calculate adjusted initial cost********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with xassum08v / 100 * Hdotsens *  ( 68 * ;
             xheaseaday - xhdd ) * ( ( ( xassum02v / 100) * ;
             (  xassum10v / 24) * xtraare ) + ( ( xassum04v ;
             / 100 ) * ( xassum10v / 24 ) * xrdtare ) + ;
             ( ( xassum03v / 100 ) * xhosmedare ) + ;
             ( ( xassum06v / 100 ) * ( xassum10v / 24 ) * ;
             xadmare ) + ( ( xassum01v / 100 ) * ( xassum10v ;
             / 24 ) * xbarare ) + ( xassum05v / 100 * ;
             ( xassum10v / 24 ) * xcomfacare ) )


* heaenesav end

********** calculate cooling energy saved **********
```

```
* cooenesav start

if xaclogtst = 1
      replace cooenesav ;
         with Hdotsenshr * 5 * xassum08v / 100 * xsacdbh * ( ( ;
              xassum02v / 100 * xtraare ) + ( xassum04v / ;
              100 * xrdtare ) + ( xassum03v / 100 * ;
              xhosmedare ) + ( xassum06v / 100 * xadmare ;
              ) + ( xassum01v / 100 * xbarare ) + ( ;
              xassum05v / 100 * xcomfacare ) ) + ;
              Hdotlathr * 5 * xassum09v / 100 * xsacdbh * ( ( ;
              xassum02v / 100 * xtraare ) + ( xassum04v / ;
              100 * xrdtare ) + ( xassum03v / 100 * ;
              xhosmedare ) + ( xassum06v / 100 * xadmare ;
              ) + ( xassum01v / 100 * xbarare ) + ( ;
              xassum05v / 100 * xcomfacare ) )
else
      replace cooenesav ;
         with 0
endif

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav / xassum07v

* eleenesav end

*********Calculate baseload demand saved***********

* basdemsav start

replace basdemsav ;
 with 0

* basdemsav end

*********Calculate summer demand saved*************

* sumdemsav start

      replace sumdemsav ;
        with Udem * 1.5 * numecouni * 1 / 12000

* sumdemsav end

********** calculate gas fuel saved **********.
```

```
* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ;
          / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ) ;
          + ( ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ) ;
          + ( ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ) ) ;
          * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ;
          / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ) ;
          + ( ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ) ;
          + ( ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ) ) ;
          * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
```

```
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ;
          / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ) ;
          + ( ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ) ;
          + ( ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ) ) ;
          * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

**********Calculate Lbs. of CFC's displaced**************

* cfcdisp start

replace cfcdisp ;
 with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start
```

```
replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Evaporative Precooling of Makeup Air

Background. The sensible cooling load of a building can be reduced by precooling the incoming air with an indirect evaporative cooler. The drybulb temperature of the intake air is lowered through the cooling effect of evaporation. The degree of cooling that can be achieved depends on regional climatic conditions (e.g., the difference between the dry and wet bulb temperatures). The dry-bulb temperature can theoretically be lowered to the wet-bulb temperature through evaporation, but not below. The evaporative cooling efficiency is a measure of how close the dry-bulb temperature can be brought to the wet-bulb temperature.

Facility assumptions. This ECO was applied to percentages of barracks, training, medical, R&D, community, and administration buildings. It is assumed that ventilation occurred 12 hr per day (except medical, which was 24 hr) and that the ventilation rate is 100 cfm per thousand feet of building area.

Sources. Sliwinski, et al. February 1979; Product literature from Aztec Sensible Cooling.

Assumptions file.

```
REEP ECO REPORT                                              Page  1
07/08/94

ECO:  Evap. Pre-Cool Air

FIELD         DESCRIPTION                                      VALUE
--------------------------------------------------------------------
ECO           Energy Opportunity                 Evap. Pre-Cool Air
UNIT          Unit                                             Units
ECOTYPE       Energy Opportunity Type                Heating/Cooling
PROGRAM       Rules File (Program) Name                     evapcool
CAPCOST       Capital Cost                                  10000.00
RECURCOST     Recurring Cost                                    0.00
ECONLIFE      Economic Life                                    15.00
DISCQTY       Discount Quantity                                10.00
```

ASSUM01	ECO Assumption 01	Barracks % Applicable
ASSUM01V	ECO Assumption 01 Value	30.00
ASSUM02	ECO Assumption 02	Training % Applicable
ASSUM02V	ECO Assumption 02 Value	20.00
ASSUM03	ECO Assumption 03	Medical % Applicable
ASSUM03V	ECO Assumption 03 Value	80.00
ASSUM04	ECO Assumption 04	R & D % Applicable
ASSUM04V	ECO Assumption 04 Value	50.00
ASSUM05	ECO Assumption 05	Community % Applicable
ASSUM05V	ECO Assumption 05 Value	50.00
ASSUM06	ECO Assumption 06	Administration % Applicable
ASSUM06V	ECO Assumption 06 Value	50.00
ASSUM07	ECO Assumption 07	Chiller COP
ASSUM07V	ECO Assumption 07 Value	3.00
ASSUM08	ECO Assumption 08	Efficiency of Indirect Cooling
ASSUM08V	ECO Assumption 08 Value	80.00
ASSUM09	ECO Assumption 09	Hours per day ventilation
ASSUM09V	ECO Assumption 09 Value	12.00

Rules file.

```
* This is the ventheat.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********* THIS ANALYSIS IS ADAPTED FROM THE VENTILATION HEAT RECOVERY
ANALYSIS **********

********* calculation of the temperature difference *********
********* between the average wet bulb temp and *************
********* average dry bulb temp in 80-84 and 85-89***********
********* data bins to use with evap. cooling efficiency ****

*** average the mean wet-bulb temps from the 80-84 and 85-89 bins ***
            Twb = 100.00
            Twb = ( ( xmcwb8084 + xmcwb8589 ) / 2 )
        *** The average dry-bulb temp. is obvious ***
            Tdb = 100.00
            Tdb = 84.5
        *** Calculate the deltaT *********************
            deltaT = 100.0
            deltaT = Tdb - Twb

********** calculate number of ECO units **********

* numecouni start
```

```
replace numecouni ;
   with ( 2 * xassum02v / 100 * xtraare / 22 ) + ( 3 * ;
        xassum04v / 100 * xrdtare / 36 ) + ( xassum03v ;
        / 100 * xhosmedare / 16 ) + ( 1.25 * xassum06v ;
        / 100 * xadmare / 15 ) + ( 3 * xassum01v / 100 ;
        * xbarare / 45.6 ) + ( xassum05v / 100 * ;
        xcomfacare / 10.2 ) * ( 1 - penfac )

* numecouni end

**********Select Project Size Factor*************

do comcalc0

**********Calculate adjusted initial cost********

* inicos start

replace inicos ;
 with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

if xaclogtst = 1
      replace cooenesav ;
         with ( 108 * deltaT * xassum08v / 100 * xsacdbh * ;
              ( ( xassum02v / 100 * xtraare ) + ( xassum04v / ;
              100 * xrdtare ) + ( xassum03v / 100 * ;
              xhosmedare ) + ( xassum06v / 100 * xadmare ;
              ) + ( xassum01v / 100 * xbarare ) + ( ;
              xassum05v / 100 * xcomfacare ) ) * ( 1 / ;
              1000 ) * ( 1 / 1000 ) )
else
      replace cooenesav ;
         with 0
endif

* cooenesav end
```

```
********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav / xassum07v

* eleenesav end

*********Calculate baseload demand saved***********

* basdemsav start

replace basdemsav ;
 with 0

* basdemsav end

*********Calculate summer demand saved*************

* sumdemsav start

replace sumdemsav ;
 with numecouni * 1.5 * 1 / 12000 * 100 * 60;
      * .24 * .075 * ( deltaT * xassum08v / 100 )

* sumdemsave end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ;
          / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ) ;
          + ( ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ) ;
          + ( ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ) ) ;
          * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end
```

```
********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ;
          / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ) ;
          + ( ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ) ;
          + ( ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ) ) ;
          * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ;
          / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ) ;
          + ( ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ) ;
          + ( ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ) ) ;
          * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start
```

```
replace watvolsav ;
   with 0

* watvolsav end

**********Calculate Lbs. of CFC's displaced**************

* cfcdisp start

replace cfcdisp ;
 with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2
* SECTION 3 - ECO specific calculations that override common calculations
```

Desuperheaters for Family Housing

Background. A desuperheater recovers heat from the hot gases generated by the air conditioning of family housing. This recovered energy is used to heat water for domestic use. Family housing uses a significant amount of the Army's hot water, so the desuperheater helps to offset the cost of heating water. The desuperheaters also provide an increase in the efficiency of the air conditioners, which results in more energy savings.

Desuperheater characteristics and facility assumptions. The desuperheater ECO is applied to all family housing.

Desuperheaters algorithm. The desuperheaters algorithm bases energy savings on the difference in energy consumption between the old AC unit and the unit retrofitted with the desuperheater. The energy savings are based on the increase in AC efficiency due to the desuperheater. This ECO also accounts for the energy saved by the desuperheater because it provides hot water.

Assumptions file.

```
REEP ECO REPORT                                                Page  1
07/08/94

ECO:  FH Desuperheaters

FIELD        DESCRIPTION                                         VALUE
-----------------------------------------------------------------------
ECO          Energy Opportunity                       FH Desuperheaters
UNIT         Unit                                              Desprhtrs
ECOTYPE      Energy Opportunity Type                   Heating/Cooling
PROGRAM      Rules File (Program) Name                         desuperh
CAPCOST      Capital Cost                                        700.00
RECURCOST    Recurring Cost                                        0.00
ECONLIFE     Economic Life                                        20.00
DISCQTY      Discount Quantity                                    10.00
ASSUM01      ECO Assumption 01                         FH KSF per AC unit
ASSUM01V     ECO Assumption 01 Value                               1.50
ASSUM02      ECO Assumption 02                        AC unit size (tons)
ASSUM02V     ECO Assumption 02 Value                               2.50
ASSUM03      ECO Assumption 03                        Seer of old AC unit
ASSUM03V     ECO Assumption 03 Value                               8.00
ASSUM04      ECO Assumption 04                      AC unit wattage (kW)
ASSUM04V     ECO Assumption 04 Value                               3.75
ASSUM05      ECO Assumption 05          Recoverable heat (Btu/hr per to
ASSUM05V     ECO Assumption 05 Value                            2500.00
ASSUM06      ECO Assumption 06              Reduction in AC energy usage
ASSUM06V     ECO Assumption 06 Value                               0.15
ASSUM07      ECO Assumption 07                Water tank temperature (F)
ASSUM07V     ECO Assumption 07 Value                             150.00
ASSUM08      ECO Assumption 08          Hot water per household (gallon
ASSUM08V     ECO Assumption 08 Value                              70.00
ASSUM09      ECO Assumption 09          AC peak demand diversity before
ASSUM09V     ECO Assumption 09 Value                              95.00
ASSUM10      ECO Assumption 10           AC peak demand diversity after
ASSUM10V     ECO Assumption 10 Value                              92.00
```

Rules file.

```
* This is the desuperh.prg program
```

```
* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units *********

* numecouni start

if xassum01v = 0
      replace numecouni ;
         with 0
else
      if xaclogtst = 1
            replace numecouni ;
               with (xfamhouare / xassum01v) * ( 1 - penfac )
      else
            replace numecouni ;
               with 0
      endif
endif

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

if xfulloacoo * numecouni * xassum02v * xassum05v / ;
      1000000 > (xassum07v - xgrotem) * 8.3 * ;
      xassum08v * xcooseaday * numecouni / 1000000
      replace heaenesav ;
         with (xassum07v - xgrotem) * 8.3 * xassum08v * ;
                  xcooseaday * numecouni / 1000000
else
      replace heaenesav ;
         with xfulloacoo * numecouni * xassum05v * xassum02v ;
```

```
                    / 1000000
endif

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with xfulloacoo * numecouni * xassum04v * xassum06v * ;
         3.412 / 1000

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

if xghp75con + xghp75cap = 0
      replace eleenesav ;
         with cooenesav + heaenesav / .97
else
      x = xghp75con + xohp75con + xchp75con
      if x = 0
            replace eleenesav ;
               with cooenesav
      else
            replace eleenesav ;
               with cooenesav + heaenesav /.97. * ( 1 - ( ;
                    xghp75con / (xghp75con + xohp75con + ;
                    xchp75con ) ) )
      endif
endif

* eleenesav end

********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with  0

* basdemsav end

******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
```

```
   with xassum04v * numecouni * ( ( xassum09v ;
      - xassum10v ) / 100 )

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

if xghp75cap + xghp75con > 0
      x = xghp75con + xohp75con + xchp75con
      if x = 0
            replace gasenesav ;
               with 0
      else
            replace gasenesav ;
               with ( heaenesav / .55 ) * xghp75con / ( ;
                    xghp75con + xohp75con + xchp75con )
      endif
else
      replace gasenesav ;
         with 0
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water volume saved **********

* watvolsav start

replace watvolsav ;
   with 0
```

```
* watvolsav end

***** Calculate Lbs. of CFCs displaced *****

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Seal Ducts in Family Housing

Background. Typically, all houses have duct leaks that can cause substantial output losses during heating and cooling seasons. These losses can prevent a properly sized piece of equipment from meeting the load, which adversely affects the occupant's comfort. When the ducts are repaired, the HVAC equipment does not have to run as long to meet the load. This is because a higher percentage of the HVAC equipment's output is reaching the conditioned space.

Duct leakage characteristics. Duct leakage repair is a low cost ECO that was applied to family housing.

Duct leakage algorithms. The algorithms for the duct leak repair ECO are based on blower door testing done on the family housing stock at Fort Hood, TX. The blower door tests were performed on several different types of family housing buildings. This resulted in an average duct leakage for family housing stock. The energy savings are calculated by multiplying the run time of the HVAC equipment times the Btu output of the equipment times the average duct leakage (as a percentage).

Assumptions file.

```
REEP ECO REPORT                                                    Page  1
07/08/94

ECO:  FH Duct Seals

FIELD      DESCRIPTION                                               VALUE
------------------------------------------------------------------------
ECO         Energy Opportunity                               FH Duct Seals
UNIT        Unit                                                    Houses
ECOTYPE     Energy Opportunity Type                        Heating/Cooling
PROGRAM     Rules File (Program) Name                             ductseal
CAPCOST     Capital Cost                                            150.00
RECURCOST   Recurring Cost                                            0.00
ECONLIFE    Economic Life                                            20.00
DISCQTY     Discount Quantity                                        30.00
ASSUM01     ECO Assumption 01                           FH KSF per furnace
ASSUM01V    ECO Assumption 01 Value                                   1.50
ASSUM02     ECO Assumption 02                       Efficiency of old furnace
ASSUM02V    ECO Assumption 02 Value                                  65.00
ASSUM03     ECO Assumption 03                   Furnace output rating (Btu)
ASSUM03V    ECO Assumption 03 Value                               60000.00
ASSUM04     ECO Assumption 04                            AC unit size (Btu/hr)
ASSUM04V    ECO Assumption 04 Value                               30000.00
ASSUM05     ECO Assumption 05                           Seer of old AC unit
ASSUM05V    ECO Assumption 05 Value                                   8.00
ASSUM06     ECO Assumption 06                            KSF applicable (%)
ASSUM06V    ECO Assumption 06 Value                                  75.00
ASSUM07     ECO Assumption 07                        Typical duct losses (%)
ASSUM07V    ECO Assumption 07 Value                                   7.60
```

Rules file.

```
* This is the ductseal.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc
```

```
********** calculate number of ECO units **********

* numecouni start

if xassum01v = 0
  replace numecouni ;
     with 0
else
  replace numecouni ;
     with xfamhouare * ( xassum06v / 100 ) / xassum01v ;
     * ( 1 - penfac )
endif

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

*inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with xfuloheafh * numecouni * ;
            ( xassum03v / 1000000 ) * ( xassum07v / 100 )

* heaenesav end

********** calculate cooling energy saved ***********

* cooenesav start

if xaclogtst = 1
      replace cooenesav ;
         with xfulloacoo * numecouni * xassum04v / ;
                 1000000 * ( xassum07v / 100 )
else
      replace cooenesav with 0
endif

* cooenesav end
```

```
********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav / ( xassum05v / 3.412 )

* eleenesav end

********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with  0

* basdemsav end

******** calculate summer demand fuel saved *******

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

if xassum02v = 0
      replace gasenesav ;
         with 0
else
      replace gasenesav ;
         with heaenesav / ( xassum02v / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********
```

```
* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

*********** Calculate Lbs. of CFCs displaced *************

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end


do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Family Housing Flame Retention Burners for Oil Boilers

Background. The installation of oil burners using flame retention technology can improve the efficiency of residential oil burners. Fuel use is reduced because less excess air is required. The installation of new burners provides a lower-cost alternative to complete replacement of the oil boiler.

Facility assumptions. This ECO is only applied to family housing units in regions without air conditioning. Within these regions, the ECO is applied to half of the housing. Under these restrictions, it is assumed that only homes with hot water heating systems are considered for the retrofit and not homes with furnaces.

Uncited sources for this section. This ECO analysis follows the analysis for the Family Housing High Efficiency Furnace ECO. Other information was gained from product literature from Reillo Corporation of America. Phone discussions with Roger McDonald, Researcher, Brookhaven National Laboratory, 24 February 1994.

Assumptions file.

```
REEP ECO REPORT                                                    Page 1
07/08/94

ECO:  FH Flame Ret. Burners

FIELD      DESCRIPTION                                              VALUE
-------------------------------------------------------------------------
ECO         Energy Opportunity                      FH Flame Ret. Burners
UNIT        Unit                                                  Burners
ECOTYPE     Energy Opportunity Type                       Heating/Cooling
PROGRAM     Rules File (Program) Name                            fhflameb
CAPCOST     Capital Cost                                           400.00
RECURCOST   Recurring Cost                                           0.00
ECONLIFE    Economic Life                                           15.00
DISCQTY     Discount Quantity                                       30.00
ASSUM01     ECO Assumption 01                  Ksf per Family Housing unit
ASSUM01V    ECO Assumption 01 Value                                  1.50
ASSUM02     ECO Assumption 02                       Efficiency Old Furnace
ASSUM02V    ECO Assumption 02 Value                                 65.00
ASSUM03     ECO Assumption 03             Furnace Efficiency With New Bur
ASSUM03V    ECO Assumption 03 Value                                 77.00
ASSUM04     ECO Assumption 04
ASSUM04V    ECO Assumption 04 Value                                  0.00
ASSUM05     ECO Assumption 05             Heating Density    [Btu/(ft2*HDD
ASSUM05V    ECO Assumption 05 Value                                 16.50
```

Rules files.

```
* This is the fhflameb.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xohp75con > 0 and xaclogtst = 0
      replace numecouni ;
         with xohp75con / ( xghp75con + xohp75con + ;
              xchp75con) * xfamhouare / xassum01v ;
              * ( 1 - penfac ) * .5
else
      if xohp75cap > 0 and xaclogtst = 0
            replace numecouni ;
               with xohp75cap / ( xghp75cap + xohp75cap + ;
                    xchp75cap ) * xfamhouare / xassum01v ;
                    * ( 1 - penfac ) * .5
      else
            replace numecouni ;
               with 0
      endif
endif

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with xlocind * numecouni * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start
```

```
replace heaenesav ;
   with ( 1 - ( xassum02v / xassum03v ) ) * xhdd * ;
         xassum05v * numecouni * xassum01v / 1000

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with 0

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
  with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end
```

```
********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with heaenesav

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water volume saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

*********** calculate HVAC energy cost saved **********

* henecossav start
```

```
replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Gas-Engine Driven Heat Pump for Family Housing

Background. Family housing uses a significant amount of the Army's heating/cooling energy. Heat pumps provide efficient cooling in the summer and can provide most of the heat during the winter. The gas-engine driven heat pump can replace both the furnace and the A/C unit. Since it replaces both pieces of HVAC equipment, the gas-engine driven heat pump was only applied to installations that meet the Army's air-conditioning criteria. Although this ECO does not address these capabilities, the gas-engine driven heat pump can heat water for domestic use and can also be a backup generator during electrical outages.

Gas-engine driven heat pump characteristics. This technology is relatively new and expensive. The ECO analyzes gas-engine driven heat pumps for family housing at installations that meet the Army's air-conditioning criteria. Yearly maintenance is required to change the oil, filter, and spark plugs.

Facility assumptions. This ECO was applied to family housing areas and directly replaces the existing A/C unit and furnace with a gas-engine driven heat pump.

Gas-engine driven heat pump algorithms. The gas-engine driven heat pump algorithm bases energy savings on the difference in energy consumption between the old and new units, multiplied by the number of hours the unit would run annually. The number of hours an A/C system operates is a function of climate. The differences in energy consumption are due to the high efficiency of the gas-engine driven heat pump.

Assumptions file.

```
REEP ECO REPORT                                          Page  1
07/08/94

ECO:  FH Gas Engine Drvn HP
```

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	FH Gas Engine Drvn HP
UNIT	Unit	Heat Pumps
ECOTYPE	Energy Opportunity Type	Heating/Cooling
PROGRAM	Rules File (Program) Name	gasengif
CAPCOST	Capital Cost	6800.00
RECURCOST	Recurring Cost	1.00
ECONLIFE	Economic Life	20.00
DISCQTY	Discount Quantity	10.00
ASSUM01	ECO Assumption 01	FH KSF per furnace
ASSUM01V	ECO Assumption 01 Value	1.50
ASSUM02	ECO Assumption 02	Efficiency of old furnace
ASSUM02V	ECO Assumption 02 Value	65.00
ASSUM03	ECO Assumption 03	Furnace output rating (Btu)
ASSUM03V	ECO Assumption 03 Value	60000.00
ASSUM04	ECO Assumption 04	AC unit size (tons)
ASSUM04V	ECO Assumption 04 Value	2.50
ASSUM05	ECO Assumption 05	Seer of old AC unit
ASSUM05V	ECO Assumption 05 Value	8.00
ASSUM06	ECO Assumption 06	AC unit wattage (kW)
ASSUM06V	ECO Assumption 06 Value	3.26
ASSUM07	ECO Assumption 07	Heat pump cooling COP
ASSUM07V	ECO Assumption 07 Value	0.90
ASSUM08	ECO Assumption 08	Heat pump heating COP
ASSUM08V	ECO Assumption 08 Value	1.10
ASSUM09	ECO Assumption 09	Heating Eff. of new euipment
ASSUM09V	ECO Assumption 09 Value	110.00

Rules file.

```
* This is the gasengif.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units ************

* numecouni start

if xassum01v = 0
      replace numecouni ;
         with 0
else
      if xaclogtst = 1
            replace numecouni ;
               with xfamhouare / xassum01v * ( 1 - penfac )
```

```
      else
            replace numecouni ;
               with 0
      endif
endif

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********* calculate heating energy saved***********

* heaenesav start

replace heaenesav ;
   with xfuloheafh * numecouni * ( xassum03v / 1000000 )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with xfulloacoo * numecouni * .03

* cooenesav end

********** calculate electric fuel saved ***********

* eleenesav start

replace eleenesav ;
   with cooenesav / ( xassum05v / 3.412 )

* eleenesav end

********** calculate base load fuel saved **********
```

```
* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
   with xassum06v * numecouni * .9

* sumdemsav end

********** calculate gas fuel saved ***********

* gasenesav start

replace gasenesav ;
   with ( heaenesav / ( xassum02v / 100 ) ) - ( ;
        heaenesav / ( xassum09v / 100 ) ) - ( cooenesav ;
        / xassum07v )

* gasenesav end

*********** calculate oil fuel saved ***********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

*********** calculate coal fuel saved ***********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start
```

```
replace watvolsav ;
   with 0

* watvolsav end

*********** Calculate Lbs. of CFCs displaced *************

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

*********** calculate HVAC energy cost saved ***********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Ground-Source Heat Pump for Family Housing

Background. Family housing uses a significant amount of the Army's heating and cooling energy. Heat pumps provide efficient cooling in the summer and can provide some of the heating during the winter. Ground-source heat pumps use a coil of pipe, called a slinky, placed in the ground to act as a heat source in the winter and a heat sink in the summer. The ground loop increases the efficiency of the ground-source heat pump over normal air

source heat pumps. The ground loop increases the installation cost but can be used in colder climates.

Ground-source heat pump characteristics. This ECO only analyzes ground-source heat pumps for family housing at installations that meet the Army's air-conditioning criteria. The performance of the ground source heat pump does not fluctuate like an air-source heat pump because of the much more stable ground temperatures. The ground-source heat pump is sized to meet the cooling load; so the old furnace will be required to provide backup heat.

Facility assumptions. The ground source heat pump replaces the A/C unit, but due to the low heating output, the furnace is left in place to provide backup heat during extreme cold.

Ground-source heat pump algorithms. The ground-source heat pump algorithm bases energy savings on the increased efficiency of the heat pump for cooling over a typical A/C unit. The total energy saved is the difference in energy consumption between the old and new units, multiplied by the number of hours the unit would run annually. The number of hours an A/C system operates is a function of climate.

Assumptions file.

```
REEP ECO REPORT                                              Page  1
07/08/94

ECO:   FH Ground Source HP

FIELD       DESCRIPTION                                       VALUE
-----------------------------------------------------------------------
ECO          Energy Opportunity                      FH Ground Source HP
UNIT         Unit                                             Heat Pumps
ECOTYPE      Energy Opportunity Type                     Heating/Cooling
PROGRAM      Rules File (Program) Name                          groupumf
CAPCOST      Capital Cost                                        3700.00
RECURCOST    Recurring Cost                                         0.00
ECONLIFE     Economic Life                                         20.00
DISCQTY      Discount Quantity                                     10.00
ASSUM01      ECO Assumption 01                        FH KSF per furnace
ASSUM01V     ECO Assumption 01 Value                                1.50
ASSUM02      ECO Assumption 02                    Efficiency of old furnace
ASSUM02V     ECO Assumption 02 Value                               65.00
ASSUM03      ECO Assumption 03                Furnace output rating (Btu)
ASSUM03V     ECO Assumption 03 Value                            60000.00
ASSUM04      ECO Assumption 04                        AC unit size (tons)
ASSUM04V     ECO Assumption 04 Value                                2.50
ASSUM05      ECO Assumption 05                        Seer of old AC unit
```

ASSUM05V	ECO Assumption 05 Value	8.00
ASSUM06	ECO Assumption 06	AC unit wattage (kW)
ASSUM06V	ECO Assumption 06 Value	3.75
ASSUM07	ECO Assumption 07	Heat pump seer
ASSUM07V	ECO Assumption 07 Value	13.30
ASSUM08	ECO Assumption 08	Heat pump HSPF
ASSUM08V	ECO Assumption 08 Value	8.00
ASSUM09	ECO Assumption 09	Heat pump wattage (kW)
ASSUM09V	ECO Assumption 09 Value	2.26
ASSUM10	ECO Assumption 10	Heating COP
ASSUM10V	ECO Assumption 10 Value	3.10
ASSUM11	ECO Assumption 11	BTU output
ASSUM11V	ECO Assumption 11 Value	30500.00

Rules file.

```
* This is the groupumf.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xassum01v = 0
      replace numecouni ;
         with 0
else
      if xaclogtst = 1
            replace numecouni ;
               with xfamhouare / xassum01v ;
                        * ( 1 - penfac )
      else
            replace numecouni ;
               with 0
      endif
endif

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********
```

```
* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

*********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with xfuloheafh * numecouni * ( xassum03v / 1000000 )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with xfulloacoo * numecouni * .03

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

      replace eleenesav ;
         with ( ( cooenesav / ( xassum05v / 3.412 ) ) - ( ;
          cooenesav / ( ( -.08519 * xgrotem + 17.559 ) ;
          / 3.412 ) ) ) -( ( xassum03v / xassum11v ) * ;
          ( heaenesav / ( .01667 * xgrotem ;
          + 2.2667 ) ) )

* eleenesav end

********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

******** calculate summer demand fuel saved*******
```

```
* sumdemsav start

replace sumdemsav ;
   with ( xassum06v - xassum09v ) * numecouni * .9

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
      with ( heaenesav / ( xassum02v / 100 ) )

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

*********** Calculate Lbs. of CFCs displaced *************

* cfcdisp start

replace cfcdisp ;
   with 0
```

```
* cfcdisp end

* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Electric Heat Pump for Family Housing

Background: Family housing uses a significant amount of the Army's heating and cooling energy. An air-source heat pump is much like a conventional air conditioner, but the heat pump can be reversed in the winter to provide heat. For most climates, when a heat pump is sized properly for the cooling load, the heat pump will not have enough capacity to meet the heating load. When outdoor temperatures drop below 40 °F, the efficiency of the heat pump is also very low. During extremely cold weather, reverting to the backup heat source is more economical. The heat pump can meet the heating load during the more temperate seasons, but backup heat is required during the coldest months. This retrofit consists of installing an air-source heat pump in place of the existing air conditioner. The existing furnace is left in place to provide backup heat during the winter.

Electric heat pump characteristics. This ECO only analyzes heat pumps for family housing at installations that meet the Army's air-conditioning criteria. Heat pumps do not provide economical heat during extreme cold temperatures, so the heat pump ECO is applied to regions where the average winter temperature is above 40 °F.

Assumptions file.

REEP ECO REPORT Page 1
07/08/94

ECO: FH Heat Pumps

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	FH Heat Pumps
UNIT	Unit	Heat Pumps
ECOTYPE	Energy Opportunity Type	Heating/Cooling
PROGRAM	Rules File (Program) Name	heatpumf
CAPCOST	Capital Cost	2350.00
RECURCOST	Recurring Cost	0.00
ECONLIFE	Economic Life	20.00
DISCQTY	Discount Quantity	10.00
ASSUM01	ECO Assumption 01	FH KSF per furnace
ASSUM01V	ECO Assumption 01 Value	1.50
ASSUM02	ECO Assumption 02	Efficiency of old furnace
ASSUM02V	ECO Assumption 02 Value	65.00
ASSUM03	ECO Assumption 03	Furnace output rating (Btu)
ASSUM03V	ECO Assumption 03 Value	60000.00
ASSUM04	ECO Assumption 04	AC unit size (tons)
ASSUM04V	ECO Assumption 04 Value	2.50
ASSUM05	ECO Assumption 05	Seer of old AC unit
ASSUM05V	ECO Assumption 05 Value	8.00
ASSUM06	ECO Assumption 06	AC unit wattage (kW)
ASSUM06V	ECO Assumption 06 Value	3.75
ASSUM07	ECO Assumption 07	Heat pump seer
ASSUM07V	ECO Assumption 07 Value	12.00
ASSUM08	ECO Assumption 08	Heat pump HSPF
ASSUM08V	ECO Assumption 08 Value	8.00
ASSUM09	ECO Assumption 09	Heat pump wattage (kW)
ASSUM09V	ECO Assumption 09 Value	2.50
ASSUM10	ECO Assumption 10	Del. COP/del. temp 2.35 COP@17
ASSUM10V	ECO Assumption 10 Value	0.04
ASSUM11	ECO Assumption 11	Del. BTU/del. temp 18000BTU@17
ASSUM11V	ECO Assumption 11 Value	433.33
ASSUM12	ECO Assumption 12	Winter indoor temperature
ASSUM12V	ECO Assumption 12 Value	70.00
ASSUM13	ECO Assumption 13	Window Area
ASSUM13V	ECO Assumption 13 Value	375.00
ASSUM14	ECO Assumption 14	Wall R-Value
ASSUM14V	ECO Assumption 14 Value	10.00
ASSUM15	ECO Assumption 15	Window R-Value
ASSUM15V	ECO Assumption 15 Value	2.00
ASSUM16	ECO Assumption 16	Roof R-Value
ASSUM16V	ECO Assumption 16 Value	15.00
ASSUM17	ECO Assumption 17	Floor R-Value
ASSUM17V	ECO Assumption 17 Value	5.00

```
ASSUM18     ECO Assumption 18              Heat Pump output at 17 degrees
ASSUM18V    ECO Assumption 18 Value                               1800.00
ASSUM19     ECO Assumption 19                     Heat Start Temperature
ASSUM19V    ECO Assumption 19 Value                                 70.00
ASSUM20     ECO Assumption 20                 Heat Pump COP at 17 degrees
ASSUM20V    ECO Assumption 20 Value                                  2.35
```

Rules file.

```
* This is the heatpumf.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xassum01v = 0
      replace numecouni ;
         with 0
else
      if xaclogtst = 1
            if ( 65 - xhdd / xheaseaday ) > 40
                  replace numecouni ;
                        with xfamhouare / xassum01v ;
                        * ( 1 - penfac )
            else
                  replace numecouni ;
                     with 0
            endif
      else
            replace numecouni ;
               with 0
      endif
endif

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********
```

```
* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

***** calculate furnace load before retrofit *****

furloadbr = ( ( ( ( ( xassum01v * 1000 ) ^ .5 ;
         * 4 * 8 - xassum13v ) / xassum14v ;
         + xassum13v / xassum15v ;
         + ( xassum01v * 1000 ) / xassum16v ;
         + xassum01v * 1000 / xassum17v ) * xassum12v ) ;
         - ( ( ( ( xassum01v * 1000 ) ^ .5 ;
         * 4 * 8 - xassum13v ) / xassum14v ;
         + xassum13v / xassum15v ;
         + ( xassum01v * 1000 ) / xassum16v ;
         + xassum01v * 1000 / xassum17v ) * xwindestem ) ) ;
         * 24 * ( xheaseaday / 2 ) / 1000000

********** calculate cross temperature **********

crosstemp = ( -10633.39 + ( ( ( xassum01v * 1000 ) ^ .5 ;
         * 4 * 8 - xassum13v ) / xassum14v ;
         + xassum13v / xassum15v ;
         + ( xassum01v * 1000 ) / xassum16v ;
         + xassum01v * 1000 / xassum17v ) * xassum12v ) ;
         / (xassum11v + ( ( ( xassum01v * 1000 ) ^ .5 ;
         * 4 * 8 - xassum13v ) / xassum14v ;
         + xassum13v / xassum15v ;
         + xassum01v * 1000 / xassum16v ;
         + xassum01v * 1000 / xassum17v ) )

*** calculate num of days load met by hp ******

dayloadmet = 2 * ( 0.5 * xheaseaday * crosstemp );
             / ( xassum19v - xwindestem )

*** calculate num of days of backup heat ******

daysbachea = xheaseaday - dayloadmet

********** calculate backup heat required **********

bacheareq = 2 * 0.5 * ( ( ( ( ( xassum01v * 1000 ) ;
            ^ .5 * 4 * 8 ;
         - xassum13v ) / xassum14v ;
         + xassum13v / xassum15v ;
```

```
        + xassum01v * 1000 / xassum16v ;
        + xassum01v * 1000 / xassum17v ) ;
        * ( xassum12v - xwindestem ) ) ;
        - ( xassum18v + xassum11v * ( xwindestem - 17 ) ) ;
        ) * 24 * ( daysbachea / 2 ) / 1000000

********** calculate cooling load before retrofit **********

acloadbr = xfulloacoo * numecouni * xassum04v * 12000 ;
   / 1000000

********** calculate heating load met by hp **********

hpmetloah = ( xassum18v + xassum11v ;
   * ( crosstemp - 17 ) * dayloadmet * 24 ) ;
   / 1000000

********** calculate heating load not met by hp **********

hpnotmeth = 2 * ( 0.5 * ( 0.5 * daysbachea ) ;
      * ( ( xassum18v + xassum11v * ( crosstemp - 17 ) ) ;
      - ( xassum18v + xassum11v * ( xwindestem - 17 ) ) ) ;
      + ( 0.5 * daysbachea ) * ( xassum18v ;
      + xassum11v * ( xwindestem - 17 ) ) ) ;
      * 24 / 1000000

*** calculate hp efficiency when meeting the load ***

hpeffhml = ( ( ( ( ( xassum19v - crosstemp ) / 2 ) ;
   + crosstemp ) - 17 ) * xassum10v ) ;
   + xassum20v

*** calculate hp efficiency when  not meeting the load ***

hpeffhnml = ( ( ( ( ( crosstemp - xwindestem ) / 2 ) ;
   + xwindestem ) - 17 ) * xassum10v ) ;
   + xassum20v

*********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********
```

```
* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

      replace eleenesav ;
         with ( ( acloadbr / ( xassum05v / 3.412 ) ) ;
                 - ( acloadbr / ( xassum07v / 3.412 ) ) ) ;
                 - ( hpmetloah / hpeffhml + hpnotmeth / ;
                 hpeffhnml ) * numecouni

* eleenesav end

********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
   with ( xassum06v - xassum09v ) * numecouni * .9

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

      replace gasenesav ;
         with ( ( hpmetloah + hpnotmeth ) ;
         / ( xassum02v / 100 )   ) * numecouni

* gasenesav end

********** calculate oil fuel saved **********
```

```
* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

*********** Calculate Lbs. of CFCs displaced *************

* cfcdisp start

replace cfcdisp;
   with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********
* henecossav start
```

```
replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Electric heat pump algorithms. Figure D1 shows some of the important factors used to develop the equations. The figure shows heat pump output and the heating load over the heating season. The Y-axis is the Btu output of the heat pump or the Btu heating load. The X-axis is a little more complicated. The heating season is in units of days, but by

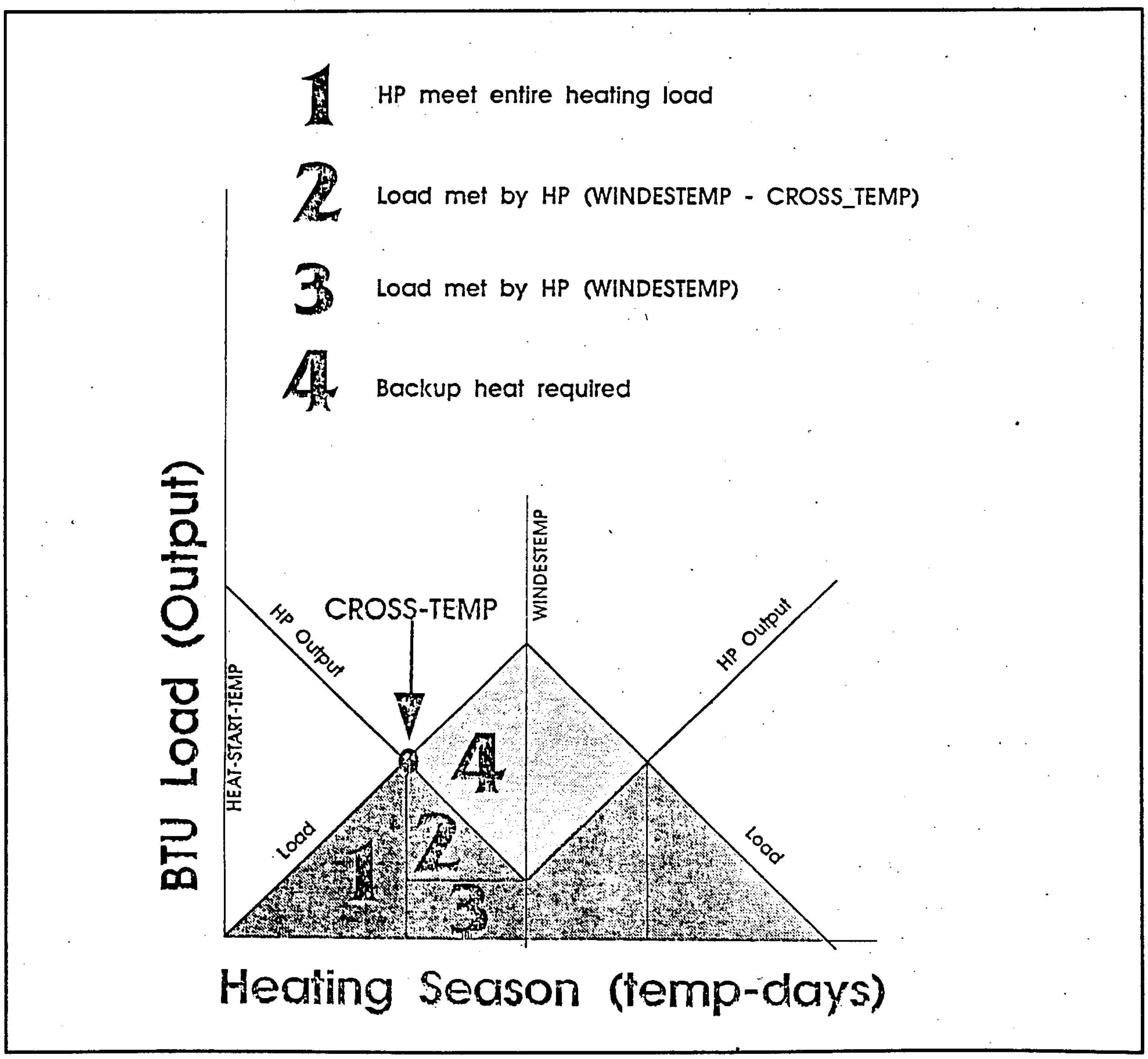


Figure D1. Heat pump output and heating load factors.

selecting a linear model and fixing the high and low temperatures for the heating season, the temperature is directly proportional to days. For example, the heating season is 180 days long and the high = heat-start-temp = 70 °F and the low = winter design temperature = 4 °F. The temperature drops from 70 °F to 4 °F (66 °F) during the first half of the heating season (90 days = 1/2 x 180). The temperature change per day of heating season = 66 °F/90 days = 0.73 °F/day. On day 45 of the heating season, the temperature = 70 °F - (0.73 °F/day × 45 days) = 37 °F. This conversion makes it easy to convert from day to temperature or vice versa, which becomes important later when the temperature is calculated at which the heat pump goes from meeting all the load to requiring backup heat. This point is referred to as the cross-over temperature (CROSS-TEMP).

The crossover temperature can be calculated by setting the equations for the heat pump output and the load equal to each other. The equation for the heat pump output is derived from the manufacturer's data. The equation for the load is derived from a heat flow calculation ($UA(T_i-T_o)$). The equation contains areas for the walls, windows, floor, and roof. The equation also uses R-values for the walls, windows, roof, and floor. The initial temperature (T_i) is equal to the winter indoor temperature (WINTER-INDOOR-TEMP = 70 °F).

Important terms and variables used.

AR = After Retrofit

BR = Before Retrofit

NUMOP = Number of opportunities

FHSIZE = Size of a typical family housing unit

FURNACE-EFF = Furnace efficiency

FURNACE-CAP = Furnace capacity

BACKUP-HEAT-REQUIRED = Amount of backup heat required to meet the load

AC-EFF = Air-conditioner efficiency

AC-CAP = Air-conditioner capacity

HP-EFF-C = Efficiency of the heat pump during cooling

HP-EFF-H-ML = Heat pump efficiency during heating when meeting the entire heating load

HP-EFF-H-NML = Heat pump efficiency during heating when not meeting the entire heating load

HP-CAP-C = Heat pump Btu output during cooling

HP-MEET-LOAD-HEATING = Amount of heat provided by the heat pump during the part of the heating season when it can meet 100 percent of the load

HP-NOT-MEET-LOAD-HEATING = Amount of heat provided by the heat pump when backup heat is also required

WALL-R-VALUE = R-value of the walls of the family housing unit

WINDOW-R-VALUE = R-value of the windows in the family housing unit

ROOF-R-VALUE = R-value of the roof of a family housing unit

FLOOR-R-VALUE = R-value of the floor in a family housing unit

WINTER-INDOOR-TEMP = Temperature inside the family housing unit during the winter

WALL-AREA = Area of the walls of a family housing unit

WINDOW-AREA = Area of the windows of a family housing unit

ROOF-AREA = Area of the roof on a family housing unit

FLOOR-AREA = Area of the floor = FHSIZE

CROSS-TEMP = The lowest temperature the heat pump can meet the heating load

DAYS-LOAD-MET-BY-HP = The number of heating season days the heat pump met the load

DAYS-BACKUP-HEAT-REQUIRED = The number of heating season days backup heat was required

HEAT-START-TEMP = The temperature at which heating is required = 65 °F

COP-PER-DEG = The change in heating COP of the heat pump for every degree above 17 °F

COP-AT-17 = The COP of the heat pump at 17 °F (heating)

T_{ave} = Average winter temperature = 65 °F - HDD/150

Q_{hp} = Heating Btu output of heat pump = 18,000 + (433.33 x (T - 17 °F))

COP_{hp} = Coefficient of performance = 2.35 + (0.038333 x (T - 17 °F))

LOAD = (WALL-AREA / WALL-R-VALUE +
WINDOW-AREA / WINDOW-R-VALUE +
ROOF-AREA / ROOF-R-VALUE + FLOOR-AREA / FLOOR-R-VALUE)
x (WINTER-INDOOR-TEMP - T_o)

where:
WALL-AREA = (FLOOR-AREA$^{1/2}$ x 4 x 8) - WINDOW-AREA
WALL-R-VALUE = 10
WINDOW-AREA = 375 sq ft
WINDOW-R-VALUE = 2
ROOF-AREA = FLOOR-AREA
ROOF-R-VALUE = 15
FLOOR-AREA = 1500 sq ft
FLOOR-R-VALUE = 5
WINTER-INDOOR-TEMP = 70°F

HP OUTPUT = 18,000 + (433.33 x (T - 17°F))

where:

Temp. (°F)	COP	Btu output
17	2.35	18,000
47	3.50	31,000

To calculate the crossover temperature ($\mathbf{T_{c\text{-}o}}$), set the equations equal to each other:

(WALL-AREA/WALL-R-VALUE + WINDOW-AREA/WINDOW-R-VALUE + ROOF-AREA/ROOF-R-VALUE + FLOOR-AREA/FLOOR-R-VALUE) x (WINTER-INDOOR-TEMP - $T_{c\text{-}o}$) = 18,000 + (433.33 x ($T_{c\text{-}o}$ - 17°F))

433.33 x $T_{c\text{-}o}$ + (WALL-AREA/WALL-R-VALUE + WINDOW-AREA/WINDOW-R-VALUE + ROOF-AREA/ROOF-R-VALUE + FLOOR-AREA/FLOOR-R-VALUE) x $T_{c\text{-}o}$ = -10633.39 + (WALL-AREA/WALL-R-VALUE + WINDOW-AREA/WINDOW-R-VALUE + ROOF-AREA/ROOF-R-VALUE + FLOOR-AREA/FLOOR-R-VALUE) x WINTER-INDOOR-TEMP

$T_{c\text{-}o}$ = (-10633.39 + (WALL-AREA/WALL-R-VALUE + WINDOW-AREA / WINDOW-R-VALUE + ROOF-AREA / ROOF-R-VALUE + FLOOR-AREA / FLOOR-R-VALUE) x WINTER-INDOOR-TEMP) / (433.33 + (WALL-AREA / WALL-R-VALUE + WINDOW-AREA / WINDOW-R-VALUE + ROOF-AREA/ROOF-R-VALUE + FLOOR-AREA / FLOOR-R-VALUE))

The crossover temperature is used to calculate the number of days the heat pump met the load and the number of days backup heat is required.

DAYS-LOAD-MET-BY-HP = (HEASEADAY x CROSS-TEMP) / (HEAT-START-TEMP - WINDESTEM)

DAYS-BACKUP-HEAT-REQUIRED = HEASEADAY - DAYS-LOAD-MET-BY-HP

Now it is possible to calculate the area in region 1 on the graph. This area is referred to as the HP-MEET-THE-LOAD-HEATING, which is when the heat pump can provide 100 percent of the heat needed. Region 1 only represents the load for the first half of the heating season. Due to symmetry, multiplying the area in region 1 by two gives the load for the entire heating season.

HP-MEET-LOAD-HEATING = (18000 + 433.33 x (CROSS-TEMP - 17) x DAYS-LOAD-MET-BY-HP x 24hrs/day) /1,000,000 Btu/MBtu

When the areas in regions 2 and 3 are calculated, the combined area is referred to as HP-NOT-MEET-LOAD-HEATING. Regions 2 and 3 represent the load for half the heating season, but due to symmetry, mutiplying by two results in the load for the entire heating season.

Area of region 2 = 0.5 x (0.5 x DAYS-BACKUP-HEAT-REQUIRED) x ((18,000 + 433.33 x (CROSS-TEMP -17)) - (18,000 + 433.33 x (WINDESTEM -17)))

Area of region 3 = (0.5 x DAYS-BACKUP-HEAT-REQUIRED) x (18,000 + 433.33 x (WINDESTEM - 17))

HP-NOT-MEET-LOAD-HEATING = 2 x (Area of region 2 + Area of region 3)

HP-NOT-MEET-LOAD-HEATING = 2 x ((.5 x DAYS-BACKUP-HEAT-REQUIRED) x (((18,000 + 433.33 x (CROSS-TEMP - 17)) - (18,000 + 433.33 x (WINDESTEM -17))) + (0.5 x DAYS-BACKUP-HEAT-REQUIRED) x (18,000 + 433.33 x (WINDESTEM - 17)))

The Area of region 4 represents the backup heat required for half the heating season. Once again symmetry comes into play: multiplying the area of region 4 by two gives the backup heat required for the entire heating season. This area is referred to as BACKUP-HEAT-REQUIRED.

Area of region 4 = 0.5 x (Load at WINDESTEM - HP output at WINDESTEM) x DAYS-BACKUP- HEAT-REQUIRED

BACKUP-HEAT-REQUIRED = 2 x Area of region 4

BACKUP-HEAT-REQUIRED = 2 x 0.5 x ((WALL-AREA/WALL-R-VALUE + WINDOW-AREA/WINDOW-R-VALUE + ROOF-AREA/ROOF-R-VALUE + FLOOR-AREA/FLOOR-R-VALUE) x (WINTER-INDOOR-TEMP - WINDESTEM) - (18,000 + 433.33 x (WINDESTEM - 17 °F)) x DAYS-BACKUP-HEAT-REQUIRED

GAS-SAVED = (FURNACE-LOAD-BR - FURNACE-LOAD-AR)/ FURNACE-EFF
FURNACE-LOAD-BR = FULOHEAFH * FURNACE-CAP
FURNACE-LOAD-AR = BACKUP-HEAT-REQUIRED

ELEC-SAVED = (AC-LOAD/AC-EFF - AC-LOAD/HP-EFF-C) - (HP-MEET-LOAD-HEATING /HP-EFF-H-ML + HP-NOT-MEET-LOAD-HEATING/HP-EFF-H-NML)

AC-LOAD = FULLOACOO * AC-CAP

HP-LOAD-COOLING-AR = FULLOACOO * HP-CAP-C

HP-EFF-H-ML = ((HEAT-START-TEMP - CROSS-TEMP)/2) + CROSS-TEMP) - 17)* COP-PER-DEG) + COP-AT-17

HP-EFF-H-ML = ((CROSS-TEMP - WINDESTEM)/2) + WINDESTEM) - 17)* COP-PER-DEG) + COP-AT-17

Table D4. Wall and Window R-values for temperature range of 4 to 60 °F.

Wall R-Value	Window R-Value	Roof R-Value	Floor R-value	Winter Indoor Temp
10	2	15	5	70
Wall Area	Window Area	Roof Area	Floor Area	
864.35	375	1500	1500	
	Heat Pump Can Meet Load Down to:		33.00	°F
Temperature	Load	HP Output	Met The Load?	Backup Required
60	6739.35	36633.19	yes	no
58	8087.23	35766.53	yes	no
56	9435.10	34899.87	yes	no
54	10782.97	34033.21	yes	no
52	12130.84	33166.55	yes	no
50	13478.71	32299.89	yes	no
48	14826.58	31433.23	yes	no
46	16174.45	30566.57	yes	no
44	17522.32	29699.91	yes	no
42	18870.19	28833.25	yes	no
40	20218.06	27966.59	yes	no
38	21565.93	27099.93	yes	no
36	22913.81	26233.27	yes	no
34	24261.68	25366.61	yes	no
32	25609.55	24499.95	no	1109.60
30	26957.42	23633.29	no	3324.13
28	28305.29	22766.63	no	5538.66
26	29653.16	21899.97	no	7753.19
24	31001.03	21033.31	no	9967.72
22	32348.90	20166.65	no	12182.25
20	33696.77	19299.99	no	14396.78
18	35044.64	18433.33	no	16611.31
16	36392.52	17566.67	no	18825.85
14	37740.39	16700.01	no	21040.38
12	39088.26	15833.35	no	23254.91
10	40436.13	14966.69	no	25469.44
8	41784.00	14100.03	no	27683.97
6	43131.87	13233.37	no	29898.50
4	44479.74	12366.71	no	32113.03

Days Of Heating Season 180.00	Winter Design Temperature 15.00	Heat Start Temperature 65.00	Load Met by Heat Pump Temperature 33.00
Days Load Met By the Heat Pump 118.81	Days Backup Heat Required 61.19	Total Days 180.00	
Load Met By the Heat Pump 9.90	Load Met By the Heat Pump 30.89	Total Load MBtu By Heat Pump 40.79	
Backup Heat Required 0.00	Backup Heat Required 14.64	Total Load MBtu From Backup 14.64	

High Efficiency Gas Furnaces for Family Housing

Background. Family Housing uses a significant portion of the Army's heating energy. Replacing the older furnaces in these buildings with new high efficiency condensing units with pulse combustion could reduce fuel usage and costs up to 30 percent. Buildings best suited to conversion are those that have gas-fired furnaces.

High efficiency furnace conclusions. Based on the analysis, high efficiency furnaces exhibit significant potential for energy savings, but the potential is only applicable in cold climates where sufficient heating loads generate the payback. Simply changing furnaces is fairly expensive and the Army pays, in general, a low price for natural gas. Paybacks on the various installations vary according to energy prices and weather patterns.

Assumptions file.

```
REEP ECO REPORT                                                   Page 1
09/01/94

ECO:  FH HiEff Gas Furn

FIELD       DESCRIPTION                                            VALUE
-------------------------------------------------------------------------
ECO         Energy Opportunity                         FH HiEff Gas Furn
UNIT        Unit                                                Furnaces
ECOTYPE     Energy Opportunity Type                      Heating/Cooling
PROGRAM     Rules File (Program) Name                           gasfurnf
CAPCOST     Capital Cost                                         1843.00
RECURCOST   Recurring Cost                                          0.00
ECONLIFE    Economic Life                                           0.00
DISCQTY     Discount Quantity                                      10.00
ASSUM01     ECO Assumption 01                          FH KSF per furnace
ASSUM01V    ECO Assumption 01 Value                                 1.50
ASSUM02     ECO Assumption 02                    Efficiency of old furnace
ASSUM02V    ECO Assumption 02 Value                                65.00
ASSUM03     ECO Assumption 03                    Efficiency of new furnace
ASSUM03V    ECO Assumption 03 Value                                91.00
ASSUM04     ECO Assumption 04                     Elec. cons. delta old/new
ASSUM04V    ECO Assumption 04 Value                                 0.04
```

Rules file.

```
* This is the gasfurnf.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********
```

```
do comcalc

********** calculate number of ECO units **********

* numecouni start

if xghp75con > 0 and xaclogtst = 1
      replace numecouni ;
         with ( 1 - penfac ) * xghp75con / ( xghp75con ;
                  + xohp75con + xchp75con ) * xfamhouare ;
                  / xassum01v
else
      if xghp75cap > 0 and xaclogtst = 1
            replace numecouni ;
               with ( 1 - penfac ) * xghp75cap / ( xghp75cap ;
            + xohp75cap + xchp75cap ) * xfamhouare ;
            / xassum01v
      else
      if xghp75con > 0 and xaclogtst = 0
      replace numecouni ;
            with ( 1 - penfac ) * xghp75con / ;
             ( xghp75con + xohp75con + xchp75con ) ;
                  * xfamhouare / xassum01v * .5
      else
      if xghp75cap > 0 and xaclogtst = 0
      replace numecouni ;
            with ( 1 - penfac ) * xghp75cap / ;
                  ( xghp75cap + xohp75cap + ;
                  xchp75cap ) * xfamhouare ;
             / xassum01v * .5

      else
      replace numecouni ;
            with 0
          endif
      endif
      endif
endif

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with xlocind * numecouni * xcapcost * prosizfac
```

```
* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with ( 1 - ( xassum02v / xassum03v ) ) * xhdd * 16.5 ;
        * numecouni * xassum01v / 1000

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
    with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with xhdd * ( -xassum04v ) * 3.412 / 1000 * numecouni

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
  with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start
```

```
replace gasenesav ;
   with heaenesav

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********.

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water volume saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0
```

```
* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

High-Efficiency Oil Furnaces for Family Housing

Background. The replacement of older, inefficient oil furnaces with new high-efficiency models in family housing units can save significant fuel oil during the heating season. This ECO considers the improvement in furnace efficiency and the resulting energy and financial savings.

Facility assumptions. This ECO applies to family housing only. It assumes that each family housing unit is 1500 sq ft in size. Only a percentage of the housing at each installation is considered to have an oil-fired furnace. This percentage is based on the percentage of fuel oil consumption (by residential-size units) relative to consumption of other fuels installation-wide. In areas without air conditioning, it is assumed that half of the homes have hot-water systems and do not apply to this retrofit.

Uncited sources. This analysis is based on the analysis for Family Housing High Efficiency Gas Furnace retrofit, product literature from and discussions with the National Sales Department of Coleman/Evcon Industries and Bill Enders, Customer Service Department of WeatherKing, 9 March 1994.

Assumptions file.

```
REEP ECO REPORT                                          Page  1
07/08/94

ECO:  FH HiEff Oil Furn

FIELD       DESCRIPTION                                    VALUE
----------------------------------------------------------------
ECO          Energy Opportunity                FH HiEff Oil Furn
UNIT         Unit                                       Furnaces
```

ECOTYPE	Energy Opportunity Type	Heating/Cooling
PROGRAM	Rules File (Program) Name	fhoilfun
CAPCOST	Capital Cost	1000.00
RECURCOST	Recurring Cost	0.00
ECONLIFE	Economic Life	20.00
DISCQTY	Discount Quantity	10.00
ASSUM01	ECO Assumption 01	Family Housing ksf/Furnace
ASSUM01V	ECO Assumption 01 Value	1.50
ASSUM02	ECO Assumption 02	Efficiency Old Furnace
ASSUM02V	ECO Assumption 02 Value	65.00
ASSUM03	ECO Assumption 03	Efficiency New Furnace
ASSUM03V	ECO Assumption 03 Value	81.00
ASSUM04	ECO Assumption 04	Heating Density [Btu/(ft2*HDD)]
ASSUM04V	ECO Assumption 04 Value	16.50

Rules file.

```
* This is the fhoilfun.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xohp75con > 0 and xaclogtst = 1
      replace numecouni ;
         with xohp75con / ( xghp75con + xohp75con + ;
              xchp75con) * xfamhouare / xassum01v ;
              * ( 1 - penfac )
else
      if xohp75cap > 0 and xaclogtst = 1
            replace numecouni ;
               with xohp75cap / ( xghp75cap + xohp75cap + ;
                    xchp75cap ) * xfamhouare / xassum01v ;
                    * ( 1 - penfac )
      else
            if xohp75con > 0 and xaclogtst = 0
            replace numecouni ;
             with xohp75con / ( xghp75con + xohp75con + ;
                  xchp75con) * xfamhouare / xassum01v ;
                 * ( 1 - penfac ) * .5
            else
                  if xohp75cap > 0 and xaclogtst = 0
                  replace numecouni ;
```

```
                    with xohp75cap / ( xghp75cap + xohp75cap + ;
                        xchp75cap ) * xfamhouare / xassum01v ;
                         * ( 1 - penfac ) * .5
                         else
                               replace numecouni ;
                               with 0
                   endif
             endif
       endif
endif

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with xlocind * numecouni * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with ( 1 - ( xassum02v / xassum03v ) ) * xhdd * ;
        xassum04v * numecouni * xassum01v / 1000

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start
```

```
replace eleenesav ;
   with 0

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
  with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with heaenesav

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end
```

```
********** calculate water volume saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

*********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

High Efficiency A/C Units for Family Housing

Background. Air-conditioning of family housing can contribute significantly to an installation's electrical energy consumption and demand charges. The degree to which these systems impact overall electrical costs is primarily a function of climate and energy rates. This ECO models the replacement of older inefficient air-conditioning systems with new high efficiency units. This ECO also includes replacing the existing "A" coil. Connecting a high efficiency A/C unit to the old "A" coil would severely limit the system's overall efficiency. The high efficiency units draw less current and contribute less to the energy demand of an installation.

Facility assumptions. Due to the method used to model the A/C units, no thermal characteristics for family housing were required to evaluate this ECO. Family housing units were modeled as 1,500 sq ft each; however, this number was only used to determine the number of opportunities at each installation. It was assumed that each 1,500 sq ft house was served by a 2.5 ton air-conditioning unit. The demand diversity factor assumes that at no time will more than 90 percent of all units be running simultaneously.

Air-conditioning algorithms. The air-conditioning algorithm bases energy savings on the difference in energy consumption between the old and new units, multiplied by the number of hours the unit would run annually. The number of hours an A/C system operates is a function of climate. The kiloWatt (kW) demand savings is calculated using manufacturer's data for kW. The savings is the difference between the new and the old, multiplied times the number of opportunities.

Assumptions file.

```
REEP ECO REPORT                                              Page  1
07/08/94

ECO:  FH High SEER AC

FIELD       DESCRIPTION                                        VALUE
--------------------------------------------------------------------
ECO         Energy Opportunity                          FH High SEER AC
UNIT        Unit                                                   ACs
ECOTYPE     Energy Opportunity Type                    Heating/Cooling
PROGRAM     Rules File (Program) Name                         acunitfh
CAPCOST     Capital Cost                                       1350.00
RECURCOST   Recurring Cost                                        2.00
ECONLIFE    Economic Life                                        20.00
DISCQTY     Discount Quantity                                    10.00
ASSUM01     ECO Assumption 01                        FH KSF per furnace
ASSUM01V    ECO Assumption 01 Value                               1.50
```

ASSUM02	ECO Assumption 02	SEER of new AC unit
ASSUM02V	ECO Assumption 02 Value	12.00
ASSUM03	ECO Assumption 03	Demand wattage decrease (Kw)
ASSUM03V	ECO Assumption 03 Value	1.25
ASSUM04	ECO Assumption 04	Diversity factor
ASSUM04V	ECO Assumption 04 Value	0.90
ASSUM05	ECO Assumption 05	SEER of old AC unit
ASSUM05V	ECO Assumption 05 Value	8.00
ASSUM06	ECO Assumption 06	A/C Capacity BTU/HR
ASSUM06V	ECO Assumption 06 Value	30000.00

Rules file.

```
* This is the acunitfh.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xaclogtst = 1
      replace numecouni ;
         with xfamhouare / xassum01v ;
                 * ( 1 - penfac )
else
      replace numecouni ;
         with 0
endif

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end
```

```
********** calculate heating energy saved ***********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with ( ( ( numecouni * xfulloacoo * xassum06v ) ;
    / ( xassum05v / 3.412 ) ) - ( ( numecouni ;
     * xfulloacoo * xassum06v ) / ( xassum02v ;
      / 3.412 ) ) ) / 1000000

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav

* eleenesav end

********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with  0

* basdemsav end

******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
   with xassum03v * numecouni * xassum04v

* sumdemsav end
```

```
********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
    with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

******* Calculate Lbs. of CFCs displaced *******

* cfcdisp start

replace cfcdisp;
   with 0

* cfcdisp end


* SECTION 2 - Common and HVAC calculations
do comcalc1
```

```
********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Insulate HVAC Ducts in Family Housing

Background. A percentage of family housing units present on Army facilities lack proper insulation surrounding HVAC ducts within unconditioned spaces. These ducts are typically located in attics or crawl spaces where the conditioning air quickly loses or gains heat through the conductive duct walls. This algorithm does not account for energy savings resulting from the possible reduction of duct leakage associated with the installation of the insulation.

Ceiling insulation characteristics. This ECO assumes that a 1 in. blanket of fiberglass insulation of R-value = 3 will be installed around HVAC ducts in applicable family housing units. It is assumed that no recurring or maintenance costs are associated with the insulation.

Facility assumptions. It is assumed that this ECO is applicable to 40 percent of all family housing facilities (from the unpublished report *Evaluation of Energy Conservation Opportunities in Family Housing Buildings at Ft. Hood, Texas* by Architectural Energy Corporation, 30 June 1993). The remaining 60 percent contain either adequately insulated HVAC ducts or the ducts are not in unconditioned spaces. It is assumed that the ducts to be insulated possess no existing insulation and that the duct walls are the same temperature as the conditioning air (underestimates the temperature difference).

It is also assumed that the average family housing unit will require 150 sq ft of duct insulation and that the unconditioned space has nearly the same temperature as the outside ambient. It is assumed that the demand savings is zero.

Duct insulation conclusions. The installation of duct insulation pays off relatively well due to the low capital cost and the energy savings earned during both warm and cold seasons. Locations experiencing one or two extremes in climatic conditions pay off best, while some variation is due to local energy cost differences.

Assumptions file.

REEP ECO REPORT Page 1
09/01/94

ECO: FH Insulate Ducts

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	FH Insulate Ducts
UNIT	Unit	Sq. Ft.
ECOTYPE	Energy Opportunity Type	Heating/Cooling
PROGRAM	Rules File (Program) Name	ductinsu
CAPCOST	Capital Cost	2.31
RECURCOST	Recurring Cost	0.00
ECONLIFE	Economic Life	20.00
DISCQTY	Discount Quantity	10000.00
ASSUM01	ECO Assumption 01	% of applicable family housing
ASSUM01V	ECO Assumption 01 Value	40.00
ASSUM02	ECO Assumption 02	KW / ton cooling
ASSUM02V	ECO Assumption 02 Value	0.75
ASSUM03	ECO Assumption 03	A/C COP
ASSUM03V	ECO Assumption 03 Value	2.20
ASSUM04	ECO Assumption 04	Gas Plant Efficiency
ASSUM04V	ECO Assumption 04 Value	70.00
ASSUM05	ECO Assumption 05	Oil Plant Efficiency
ASSUM05V	ECO Assumption 05 Value	65.00
ASSUM06	ECO Assumption 06	Coal Plant efficiency
ASSUM06V	ECO Assumption 06 Value	60.00
ASSUM07	ECO Assumption 07	Summer Interior design temp (F)
ASSUM07V	ECO Assumption 07 Value	78.00
ASSUM08	ECO Assumption 08	Delta U-Value [Btu/hr*ft2*F]
ASSUM08V	ECO Assumption 08 Value	0.33
ASSUM09	ECO Assumption 09	Uninsulated Area of Ducts per H
ASSUM09V	ECO Assumption 09 Value	150.00
ASSUM10	ECO Assumption 10	Area per Family Housing Unit
ASSUM10V	ECO Assumption 10 Value	1500.00
ASSUM11	ECO Assumption 11	Diversity
ASSUM11V	ECO Assumption 11 Value	0.10

Rules File.

```
* This is the ductinsu.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with xfamhouare * 1000 * ( xassum01v / 100 ) / xassum10v ;
        * xassum09v * ( 1 - penfac )

* numecouni end

**********Select Project Size Factor*************

do comcalc0

**********Calculate adjusted initial cost********

* inicos start

replace inicos ;
 with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * xhdd * 24 * xassum08v / 1000000

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with numecouni * xcdd * 24 * xassum08v / 1000000

* cooenesav end
```

```
********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav / xassum03v

* eleenesav end

*********Calculate baseload demand saved***********

* basdemsav start

replace basdemsav ;
 with 0

* basdemsav end

*********Calculate summer demand saved*************

* sumdemsav start

replace sumdemsav ;
 with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ;
          / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ) ;
          + ( ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ) ;
          + ( ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ) ) ;
          * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end
```

```
********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) ;
            * xoilcomeff ;
            / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
            * xgascomeff ) ;
            + ( ( xohp35con + xohp7535con + xohp75con ) ;
            * xoilcomeff ) ;
            + ( ( xchp35con + xchp7535con + xchp75con ) ;
            * xcoacomeff ) ) ;
            * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) ;
            * xcoacomeff ;
            / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
            * xgascomeff ) ;
            + ( ( xohp35con + xohp7535con + xohp75con ) ;
            * xoilcomeff ) ;
            + ( ( xchp35con + xchp7535con + xchp75con ) ;
            * xcoacomeff ) ) ;
            * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start
```

```
replace watvolsav ;
   with 0

* watvolsav end

**********Calculate Lbs. of CFC's displaced**************

* cfcdisp start

replace cfcdisp ;
 with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Nominal (81%) Efficiency Furnaces for Family Housing

Background. Federal standards have increased the minimum efficiency requirements for furnaces to 78 percent beginning 1 January 1992 (PL 100-12, S.83, commonly known as the National Appliance Energy Conservation Act of 1987). Most furnace manufacturers' bottom-of-the-line models are rated 80 to 82 percent efficient. This ECO analyzes retrofitting older inefficient furnaces with nominal efficiency units. The nominal efficiency units cost significantly less than the high-efficiency furnaces, thus, although

they do not save as much energy as the high-efficiency units, their paybacks may be better.

Facility assumptions. This ECO applies only to family housing.

Nominal efficiency furnace conclusions. Some installations may have nominal efficiency furnaces pay back within 10 years. These should be considered only where high efficiency units do not meet the payback criteria.

Assumptions file.

```
REEP ECO REPORT                                                Page 1
09/01/94

ECO:  FH Nom Eff Gas Furn

FIELD       DESCRIPTION                                         VALUE
----------------------------------------------------------------------
ECO         Energy Opportunity                     FH Nom Eff Gas Furn
UNIT        Unit                                              Furnaces
ECOTYPE     Energy Opportunity Type                    Heating/Cooling
PROGRAM     Rules File (Program) Name                         nomifurf
CAPCOST     Capital Cost                                        834.00
RECURCOST   Recurring Cost                                        0.00
ECONLIFE    Economic Life                                        20.00
DISCQTY     Discount Quantity                                    10.00
ASSUM01     ECO Assumption 01                          FH KSF per furnace
ASSUM01V    ECO Assumption 01 Value                               1.50
ASSUM02     ECO Assumption 02                      Efficiency of old furnace
ASSUM02V    ECO Assumption 02 Value                              65.00
ASSUM03     ECO Assumption 03                      Efficiency of new furnace
ASSUM03V    ECO Assumption 03 Value                              81.00
ASSUM04     ECO Assumption 04                      Elec. cons. delta old/new
ASSUM04V    ECO Assumption 04 Value                               0.04
```

Rules File.

```
* This is the nomifurf.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start
```

```
if xghp75con > 0 and xaclogtst = 1
      replace numecouni ;
         with xghp75con / ( xghp75con + xohp75con + ;
              xchp75con) * xfamhouare / xassum01v ;
              * ( 1 - penfac )
else
      if xghp75cap > 0 and xaclogtst = 1
            replace numecouni ;
               with xghp75cap / ( xghp75cap + xohp75cap + ;
                    xchp75cap ) * xfamhouare / xassum01v ;
                    * ( 1 - penfac )
      else
            if xghp75con > 0 and xaclogtst = 0
                  replace numecouni ;
                        with xghp75con / ( xghp75con + xohp75con ;
                               + xchp75con) * xfamhouare / ;
                               xassum01v * ( 1 - penfac ) * .5
            else
                  if xghp75cap > 0 and xaclogtst = 0
                        replace numecouni ;
                              with xghp75cap / ( xghp75cap + ;
                                   xohp75cap + xchp75cap ) * ;
                                   xfamhouare / xassum01v * ;
                                   ( 1 - penfac ) * .5

                  else
                        replace numecouni ;
                              with 0
                  endif
            endif
      endif
endif

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with xlocind * numecouni * xcapcost * prosizfac

* inicos end
```

```
********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with ( 1 - ( xassum02v / xassum03v ) ) * xhdd * 16.5 ;
        * numecouni * xassum01v / 1000

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with xhdd * ( -xassum04v ) * 3.412 / 1000 * numecouni

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
  with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start
```

```
replace gasenesav ;
   with heaenesav

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water volume saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
```

```
   with 0

* watcossav end

*********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Programmable Thermostats in Family Housing

Background. One of the most common and readily installed retrofits for a housing occupant is a programmable thermostat that will save energy in both the cooling and heating seasons. The thermostat is a low cost, simple unit consisting of a digital temperature sensor with an actuator and a time clock with battery backup, providing the occupant with the ability to automatically vary the building temperature based on a set schedule. Units typically have four time periods per day with the ability to set weekday and weekend schedules independently. The time periods are wake-up, day-time, evening, and sleep. Each can be set independently for temperature and duration.

Programmable thermostat characteristics. Many varieties of programmable thermostats are on the market, including those with optimum morning startup. This analysis assumes a basic thermostat is used. Periods of setup and setback, along with the duration and temperature delta are defined in the facility characteristics below.

Facility assumptions. This ECO is applied to family housing only, but the concept of temperature setback (or setup) could also be readily applied to other Operation and Maintenance, Army (OMA) facilities. Because of the complexities involved in controls for larger buildings, other facilities will be analyzed separately under a different ECO in conjunction with other control options such as EMCS. Assumptions were required for the temperatures in the units, the duration of the setbacks and setups, and how many degrees were in each. Conservative assumptions were made for all. It was also necessary to assume that only a certain percentage of the housing units would be empty during the workday, allowing for setback and setup during this period.

Programmable thermostat conclusions. Based on the analysis, programmable thermostats in family housing exhibit great potential for energy savings and rapid payback. The analysis was very conservative, assuming moderate setbacks (setups) for relatively short time periods. Paybacks on the various installations vary according to energy prices and weather patterns.

Assumptions file.

```
REEP ECO REPORT                                                Page 1
09/01/94

ECO:   FH Progrmmbl Thermostats

FIELD       DESCRIPTION                                          VALUE
----------------------------------------------------------------------
ECO         Energy Opportunity                FH Progrmmbl Thermostats
UNIT        Unit                                            Thermstats
ECOTYPE     Energy Opportunity Type                    Heating/Cooling
PROGRAM     Rules File (Program) Name                        progther
CAPCOST     Capital Cost                                        95.12
RECURCOST   Recurring Cost                                       1.00
ECONLIFE    Economic Life                                       15.00
DISCQTY     Discount Quantity                                   50.00
ASSUM01     ECO Assumption 01                             FH KSF per unit
ASSUM01V    ECO Assumption 01 Value                              1.50
ASSUM02     ECO Assumption 02                        FH heating coefficient
ASSUM02V    ECO Assumption 02 Value                             16.50
ASSUM03     ECO Assumption 03                  Interior heating temp setting
ASSUM03V    ECO Assumption 03 Value                             70.00
ASSUM04     ECO Assumption 04                  Interior cooling temp setting
ASSUM04V    ECO Assumption 04 Value                             78.00
ASSUM05     ECO Assumption 05                   Hours of day heating setback
ASSUM05V    ECO Assumption 05 Value                              7.00
ASSUM06     ECO Assumption 06                      Hours of day cooling setup
ASSUM06V    ECO Assumption 06 Value                              7.00
ASSUM07     ECO Assumption 07                 Hours of night heating setback
ASSUM07V    ECO Assumption 07 Value                              7.00
ASSUM08     ECO Assumption 08                          Heating setback (F)
ASSUM08V    ECO Assumption 08 Value                              8.00
ASSUM09     ECO Assumption 09                            Cooling setup (F)
ASSUM09V    ECO Assumption 09 Value                              8.00
ASSUM10     ECO Assumption 10                     Empty daytime houses (%)
ASSUM10V    ECO Assumption 10 Value                             40.00
```

Rules file.

```
* This is the progther.prg program

* SECTION 1 - ECO specific calculations
```

```
********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xassum01v = 0
      replace numecouni ;
         with 0
else
      replace numecouni ;
         with ( 1 - penfac ) * xfamhouare / xassum01v
endif

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with xlocind * numecouni * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with ( ( xassum05v * ( xassum10v / 100 ) * ( 5 / 7 ) ;
            + xassum07v ) * xassum08v * xhdd * xassum02v * ;
            xfamhouare ) / ( 24 * 1000 * ( xassum03v - ;
            xwindestem ) ) * ( 1 - penfac )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

if ( xsumdestem - xassum04v ) = 0
      replace cooenesav ;
         with 0
else
```

```
      replace cooenesav ;
         with ( ( 5 / 7 ) * xassum06v * xassum09v * ( xassum10v ;
            / 100 ) * xcdd * 0.00172 * xfamhouare * 3.412 ) ;
          / ( 24 * 1000 * ( xsumdestem - xassum04v ) ) * ;
          ( 1 - penfac )
endif

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
  with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

x = xghp35con + xohp35con + xchp35con
if x = 0
      replace gasenesav ;
         with 0
else
      replace gasenesav ;
         with xghp35con / ( xghp35con + xohp35con ;
                  + xchp35con ) * heaenesav
endif

* gasenesav end
```

```
********** calculate oil fuel saved **********

* oilenesav start

x = xghp35con + xohp35con + xchp35con
if x = 0
      replace oilenesav ;
         with 0
else
      replace oilenesav ;
         with xohp35con / ( xghp35con + xohp35con + ;
                  xchp35con ) * heaenesav
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

x = xghp35con + xohp35con + xchp35con
if x = 0
      replace coaenesav ;
         with 0
else
      replace coaenesav ;
         with xchp35con / ( xghp35con + xohp35con + ;
                  xchp35con ) * heaenesav
endif

* coaenesav end

********** calculate water volume saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
```

```
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Install Whole-House Fans in Family Housing

Background. Within a particular temperature and humidity range, cooling can be achieved with a whole-house fan. The fan creates air movement that results in both convective and evaporative cooling for the building occupants. The convective cooling component becomes limited as the ambient dry-bulb temperature approaches the temperature of the human body, while the evaporative component is limited by the relative humidity of flowing air. Within the proper temperature and humidity range, whole-house fans can be used to supplant conventional air conditioning units with significantly less power consumption.

Whole-house fan characteristics. It is assumed that the fan must provide a volumetric air flow of 10,000 cfm to provide comfort to occupants located anywhere within a typical family housing unit of 1,500 sq ft. At this flowrate, it is assumed that the fan consumes 770 W and that the avoided air-conditioner consumes 3260 W. This ECO is not evaluated unless mechanical A/C units exist in the family housing units being considered.

Environmental considerations. The "comfort zone" for consideration of this ECO is assumed to be $80 < T_{db} < 89$ [°F] and relative humidity (Φ) < 50 percent. Outside of these limits the ECO is not evaluated. For $\Phi = 35$ percent, it is assumed that the fan can supplant the A/C for all of the cooling hours between $T_{db} = 80$ [°F] and $T_{db} = 89$ [°F]. For

35 percent < Φ < 50 percent , the cooling hours supplanted decrease linearly from the total cooling hours at Φ = 35 percent to zero cooling hours at Φ = 50 percent.

Whole-house fan algorithms.

Calculation of Relative Humidity

$$\ln(Pws)=C_8/T+C_9+C_{10}T+C_{11}T^2+C_{12}T^3+C_{13}\ln(T)$$

$$\ln(P*_{ws})=C_8/T*+C_9+C_{10}T*+C_{11}T*^2+C_{12}T*^3+C_{13}\ln(T*)$$

$$W_s=0.62198\frac{P_{ws}(T)}{P_{atm}-P_{ws}(T)}$$

$$W_s^*=0.62198\frac{P_{ws}(T^*)}{P_{atm}-P_{ws}(T^*)}$$

$$W=\frac{(1093\ -\ 0.556T*)W_s*\ -\ 0.240(T\ -\ T*)}{1093\ +\ 0.444T\ -\ T*}$$

$$\mu=\frac{W}{W_s}$$

P_{atm} = 0.000486333 * (elevation, ft) + 14.696 (derived from Ref. 6)

$$\Phi=\frac{\mu}{1-(1-\mu)\frac{Pws}{Patm}}$$

Φ = Relative humidity

(Source: Parsons 1989, pp 6, 13.)

Whole-house fan conclusions. Whole-house fans pay off well in drier, warmer climates where a significant portion of the A/C load can be replaced by the fan. Many of the

assumptions inherent in this ECO algorithm require further consideration, as does inclusion of resident-participation considerations.

Assumptions file.

```
REEP ECO REPORT                                                    Page  1
07/08/94

ECO:  FH Whole House Fans w/AC

FIELD       DESCRIPTION                                           VALUE
-------------------------------------------------------------------------
ECO         Energy Opportunity                   FH Whole House Fans w/AC
UNIT        Unit                                                     Fans
ECOTYPE     Energy Opportunity Type                       Heating/Cooling
PROGRAM     Rules File (Program) Name                            whfansfh
CAPCOST     Capital Cost                                           627.21
RECURCOST   Recurring Cost                                           0.00
ECONLIFE    Economic Life                                           20.00
DISCQTY     Discount Quantity                                       30.00
ASSUM01     ECO Assumption 01                                FH KSF per Home
ASSUM01V    ECO Assumption 01 Value                                  1.50
ASSUM02     ECO Assumption 02                 Wattage of whole house fan moto
ASSUM02V    ECO Assumption 02 Value                                770.00
ASSUM03     ECO Assumption 03                 Wattage of existing AC unit [W]
ASSUM03V    ECO Assumption 03 Value                               3750.00
ASSUM04     ECO Assumption 04                   Demand Wattage Decrease [KW]
ASSUM04V    ECO Assumption 04 Value                                  2.98
ASSUM05     ECO Assumption 05
ASSUM05V    ECO Assumption 05 Value                                  0.00
ASSUM06     ECO Assumption 06                                      AC COP
ASSUM06V    ECO Assumption 06 Value                                  2.20
```

Rules file.

```
* This is the whfansfh.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** Preliminary Calculations **********

       ********* calculation of the relative humidity (phi) to screen out
locations********
                   *********   See   ASHRAE   Fundamentals   1989   6.13
***************************************
```

```
*** calculate atmosheric pressure [psia] based on elevation ***
   Patm = 100.000
   Patm = ( -0.000486333 * xele ) + 14.696
 *** average the mean wet-bulb temps from the 80-84 and 85-89
bins, convert to Rankine ***
   Twb = 100.00
   Twb = ( ( xmcwb8084 + xmcwb8589 ) / 2 ) + 459.67
*** convert the average dry-bulb temp from the 80-84 and 85-89
bins to Rankine ***
   Tdb = 100.00
   Tdb = 84.5 + 459.67
*** calculate Pws(t*) [psia] ***
   Pwstwb = 1.0000000
     Pwstwb = EXP ( ( -10440.39708 / Twb ) - 11.2946496 - (
0.027022355 * Twb ) + ;
           ( 0.00001289036 * Twb^2 ) - ( 0.000000002478068 *
Twb^3 ) + ;
           ( 6.5459673 * LOG ( Twb ) ) )
*** calculate Ws* ***
   Wswb = 1.0000000
   Wswb = ( 0.62189 * ( Pwstwb / ( Patm - Pwstwb ) ) )
*** calculate W  ***
   W = 1.0000000
   W = ( ( ( 1093 - 0.556 * Twb ) * Wswb - 0.24 * ( Tdb - Twb )
) / ;
        ( 1093 + ( 0.444 * Tdb ) - Twb ) )
*** calculate Pws(t) [psia] ***
   Pwst = 1.0000000
    Pwst = EXP ( ( -10440.39708 / Tdb ) - ( 11.2946496 ) - (
0.027022355 * Tdb ) + ;
          ( 0.00001289036 * Tdb^2 ) - ( 0.000000002478068 *
Tdb^3 ) + ;
          ( 6.5459673 * LOG ( Tdb ) ) )
*** calculate Ws ***
   Ws = 1.0000000
   Ws = ( 0.62189 * ( Pwst / ( Patm - Pwst ) ) )
*** calculate mu ***
   mu = 1.0000000
   mu = W / Ws
*** calculate phi ***
   phi = 1.00
   phi = mu / ( 1 - ( ( 1 - mu ) * ( Pwst / Patm ) ) )

 *********  End  Calculation  of  the  relative  humidity  phi
********************************

********** calculate number of ECO units **********
```

```
* numecouni start

if xaclogtst = 1 AND phi <= .50
         replace numecouni ;
            with ( xfamhouare / xassum01v ) ;
                   * ( 1 - penfac )
else
         replace numecouni ;
            with 0
endif

* numecouni end

**********Select Project Size Factor*************

do comcalc0

**********Calculate adjusted initial cost********

* inicos start

replace inicos ;
 with numecouni * xlocind * xcapcost * prosizfac

* inicos end


********** calculate heating energy saved ***********

* heaenesav start

 replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

if phi < .35
  replace cooenesav ;
   with ( ( xhour8084 + xhour8589 ) / xsacdbh ) * ;
    xfulloacoo * ( xassum03v - xassum02v ) * ;
    numecouni * 3.412 / 1000000
else
  replace cooenesav ;
   with ( 5.0 - ( phi * 10 ) ) * ;
   ( ( xhour8084 + xhour8589 ) ;
```

```
    / xsacdbh ) * xfulloacoo * ;
    ( xassum03v - xassum02v ) ;
     * numecouni * 3.412 / 1000000
                endif

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav / xassum06v

* eleenesav end

*********Calculate baseload demand saved**********

* basdemsav start

replace basdemsav ;
 with 0

* basdemsav end

*********Calculate summer demand saved************

* sumdemsav start

replace sumdemsav ;
 with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ;
          / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ) ;
          + ( ( xohp35con + xohp7535con + xohp75con ) ;
```

```
            * xoilcomeff ) ;
            + ( ( xchp35con + xchp7535con + xchp75con ) ;
            * xcoacomeff ) ) ;
            * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) ;
            * xoilcomeff ;
            / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
            * xgascomeff ) ;
            + ( ( xohp35con + xohp7535con + xohp75con ) ;
            * xoilcomeff ) ;
            + ( ( xchp35con + xchp7535con + xchp75con ) ;
            * xcoacomeff ) ) ;
            * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) ;
            * xcoacomeff ;
            / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
            * xgascomeff ) ;
            + ( ( xohp35con + xohp7535con + xohp75con ) ;
            * xoilcomeff ) ;
            + ( ( xchp35con + xchp7535con + xchp75con ) ;
            * xcoacomeff ) ) ;
```

```
          * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

**********Calculate Lbs. of CFC's displaced**************

* cfcdisp start

replace cfcdisp ;
 with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end


do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Flame Retention Burners in Non-Family Housing

Background. The installation of oil burners using flame retention technology can improve the efficiency of residential oil boilers. Fuel use is reduced because less excess air is required. The installation of new burners provides a lower-cost alternative to complete replacement of the oil boiler.

Sources. Product literature from Riello Corporation of America and telephone discussions with Roger McDonald, Researcher. Brookhaven National Laboratory, 24 February 1994.

Assumptions file.

```
REEP ECO REPORT                                                  Page  1
07/08/94

ECO:  Flame Retention Burners

FIELD      DESCRIPTION                                             VALUE
------------------------------------------------------------------------
ECO        Energy Opportunity                    Flame Retention Burners
UNIT       Unit                                                  Burners
ECOTYPE    Energy Opportunity Type                       Heating/Cooling
PROGRAM    Rules File (Program) Name                            flameret
CAPCOST    Capital Cost                                           850.00
RECURCOST  Recurring Cost                                           0.00
ECONLIFE   Economic Life                                           15.00
DISCQTY    Discount Quantity                                       30.00
ASSUM01    ECO Assumption 01               Post-Retrofit Capacity [MBtu/hr
ASSUM01V   ECO Assumption 01 Value                                  0.60
ASSUM02    ECO Assumption 02              Pre-Retrofit Capacity [MBtu/hr]
ASSUM02V   ECO Assumption 02 Value                                  1.55
ASSUM03    ECO Assumption 03                  % oil boilers < .75 Mbtu/hr
ASSUM03V   ECO Assumption 03 Value                                 50.00
ASSUM04    ECO Assumption 04              % oil boilers .75 - 3.5 Mbtu/hr
ASSUM04V   ECO Assumption 04 Value                                 76.00
ASSUM05    ECO Assumption 05                  Seasonal Eff. post-retrofit
ASSUM05V   ECO Assumption 05 Value                                 77.00
ASSUM06    ECO Assumption 06                   Seasonal Eff. pre-retrofit
ASSUM06V   ECO Assumption 06 Value                                 70.00
```

Rules file.

```
* This is the flameret.prg program

* SECTION 1 - ECO specific calculations
```

```
********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xfulloahea = 0
         replace numecouni ;
            with 0
else
         replace numecouni ;
            with ( 1 - penfac ) * ( xohp7535cap ;
                        * xassum04v / 100 + xohp75cap * ;
                        xassum03v / 100 ) / xassum02v
endif

* numecouni end

********** Select Project Size Factor *************

do comcalc0

********** Calculate adjusted initial cost.**********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * xassum01v * xfulloahea * ;
         ( ( 100 / xassum06v ) - ( 100 / xassum05v ) )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0
```

```
* cooenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with 0

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

  replace gasenesav ;
     with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

  replace oilenesav ;
     with heaenesav

* oilenesav end

********** calculate coal fuel saved **********
```

```
 * coaenesav start

   replace coaenesav ;
      with 0

 * coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********** Calculate Lbs. of CFC's displaced **********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2
```

```
* SECTION 3 - ECO specific calculations that override common calculations
```

Pulse Combustion/Modular Boiler

Background. Buildings isolated from an installation's central heating network use about half the Army's heating energy. Replacing the older boilers in these buildings with new high-efficiency modular boilers could reduce fuel usage and costs up to 50 percent. Buildings best suited to conversion are those that have gas-fired hot water boilers in the size range of 0.5 to 1.5 MBtu/hr.

Modular boiler characteristics. The high-efficiency boilers have pulse combustion, use outside air for combustion, and have condensing heat exchangers. Conversion can be accomplished in less than 2 weeks and subsequently the boilers require only simple maintenance. The costs and assumptions are defined below (Potts 1992).

Facility assumptions. This ECO applies to all buildings except family housing. It is assumed that a certain percentage of the boiler plants are hydronic and have an average size (see assumptions below). The typical plant is replaced by two high-efficiency boilers with a rating of 40 percent of the original capacity. Seasonal efficiencies for the old and new equipment are defined below.

Modular boiler conclusions. Based on the analysis, modular boilers exhibit significant potential for energy savings but are only applicable in cold climates where heating load is sufficient to generate the pay back. The units are fairly expensive and the Army pays, in general, a low price for natural gas. Paybacks on the various installations vary according to energy prices and weather patterns.

Assumptions file.

```
REEP ECO REPORT                                                Page 1
09/01/94

ECO:  Gas Hieff Boilers

FIELD       DESCRIPTION                                         VALUE
---------------------------------------------------------------------
ECO         Energy Opportunity                      Gas Hieff Boilers
UNIT        Unit                                              Boilers
ECOTYPE     Energy Opportunity Type                   Heating/Cooling
PROGRAM     Rules File (Program) Name                        pulscomb
CAPCOST     Capital Cost                                      7611.10
RECURCOST   Recurring Cost                                       0.00
ECONLIFE    Economic Life                                       15.00
DISCQTY     Discount Quantity                                   10.00
```

ASSUM01	ECO Assumption 01	Typ. boiler plant size (MBtu/hr
ASSUM01V	ECO Assumption 01 Value	1.55
ASSUM02	ECO Assumption 02	Typ. replacement boiler size (M
ASSUM02V	ECO Assumption 02 Value	0.30
ASSUM03	ECO Assumption 03	% gas boiler < .75 Mbtu/hr
ASSUM03V	ECO Assumption 03 Value	30.00
ASSUM04	ECO Assumption 04	% gas boiler .75 - 3.5 Mbtu/hr
ASSUM04V	ECO Assumption 04 Value	24.00
ASSUM05	ECO Assumption 05	Seasonal eff. of new plants
ASSUM05V	ECO Assumption 05 Value	91.00
ASSUM06	ECO Assumption 06	Seasonal eff. of old plants
ASSUM06V	ECO Assumption 06 Value	65.00

Rules file.

```
* This is the pulscomb.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xfulloahea = 0
         replace numecouni ;
            with 0
else
         replace numecouni ;
            with ( 1 - penfac ) * ( ( ( xghp7535con * xassum04v ;
                 / 100 + xghp75con * xassum03v / 100 ) * ( ;
                 xassum06v / 100 ) / (xassum02v * xfulloahea ) + ;
                 ( ( xghp7535cap * xassum04v / 100 + ;
                 xghp75cap * xassum03v / 100 ) * 2 / ;
                 xassum01v ) ) ) / 2
endif

* numecouni end

********** Select Project Size Factor *************

do comcalc0

********** Calculate adjusted initial cost **********

* inicos start

replace inicos ;
```

```
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * xassum02v * xfulloahea * ;
            ( ( 100 / xassum06v ) - ( 100 / xassum05v ) )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with 0

* eleenesav end

********** calculate gas fuel saved **********
```

```
 * gasenesav start

   replace gasenesav ;
      with heaenesav

 * gasenesav end

********** calculate oil fuel saved **********

 * oilenesav start

   replace oilenesav ;
      with 0

 * oilenesav end

********** calculate coal fuel saved **********

 * coaenesav start

   replace coaenesav ;
      with 0


 * coaenesav end

********** calculate water saved **********

 * watvolsav start

replace watvolsav ;
   with 0

 * watvolsav end

********** Calculate Lbs. of CFC's displaced **********

 * cfcdisp start

replace cfcdisp ;
   with 0

 * cfcdisp end

 * SECTION 2 - Common and HVAC calculations

do comcalc1

********** calculate water cost saved **********

 * watcossav start
```

```
replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Nominal Efficiency Gas Boiler

Background. The replacement of older, inefficient gas-fired boilers can save a significant portion of yearly gas heating costs. It is assumed that the buildings best suited for conversion are those that have gas-fired hot water boilers in the size range of 0.5 to 1.5 MBtu/hr.

Facility assumptions. This ECO applies to all buildings except family housing. It is assumed that a certain percentage of the boiler plants are hydronic and have an average size (see assumptions below). The larger boilers are replaced by two high-efficiency boilers with a rating of 40 percent of the original capacity.

Assumptions file.

REEP ECO REPORT Page 1
07/08/94

ECO: Gas Nomeff Boiler

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	Gas Nomeff Boiler
UNIT	Unit	Boilers
ECOTYPE	Energy Opportunity Type	Heating/Cooling
PROGRAM	Rules File (Program) Name	gasboilr
CAPCOST	Capital Cost	4500.00
RECURCOST	Recurring Cost	0.00
ECONLIFE	Economic Life	15.00
DISCQTY	Discount Quantity	10.00

ASSUM01	ECO Assumption 01	Typ. Boiler Plant Size [MBtu/hr
ASSUM01V	ECO Assumption 01 Value	1.55
ASSUM02	ECO Assumption 02	Typ. Replacement Boiler Size [M
ASSUM02V	ECO Assumption 02 Value	0.30
ASSUM03	ECO Assumption 03	% Gas Boilers < .75 MBtu/hr
ASSUM03V	ECO Assumption 03 Value	30.00
ASSUM04	ECO Assumption 04	% Gas Boilers .75 - 3.5 MBtu/hr
ASSUM04V	ECO Assumption 04 Value	24.00
ASSUM05	ECO Assumption 05	Seasonal Eff. New Plants
ASSUM05V	ECO Assumption 05 Value	75.00
ASSUM06	ECO Assumption 06	Seasonal Eff. Old Plants
ASSUM06V	ECO Assumption 06 Value	65.00

Rules File

```
* This is the gasboilr.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xfulloahea = 0
        replace numecouni ;
           with 0
else
        replace numecouni ;
           with ( 1 - penfac ) * ( ( ( xghp7535con * xassum04v ;
                / 100 + xghp75con * xassum03v / 100 ) * ;
                ( xassum06v / 100 ) / (xassum02v * xfulloahea ) + ;
                ( ( xghp7535cap * xassum04v / 100 + ;
                xghp75cap * xassum03v / 100 ) * 2 / ;
                xassum01v ) ) ) / 2
endif

* numecouni end

********** Select Project Size Factor *************

do comcalc0

********** Calculate adjusted initial cost **********

* inicos start
```

```
replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * xassum02v * xfulloahea * ;
          ( ( 100 / xassum06v ) - ( 100 / xassum05v ) )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with 0
```

```
 * eleenesav end

 ********** calculate gas fuel saved **********

 * gasenesav start

   replace gasenesav ;
      with heaenesav

 * gasenesav end

 ********** calculate oil fuel saved **********

 * oilenesav start

   replace oilenesav ;
      with 0

 * oilenesav end

 ********** calculate coal fuel saved **********

 * coaenesav start

   replace coaenesav ;
      with 0

 * coaenesav end

 ********** calculate water saved **********

 * watvolsav start

replace watvolsav ;
   with 0

 * watvolsav end

 ********** Calculate Lbs. of CFC's displaced **********

 * cfcdisp start

replace cfcdisp ;
   with 0

 * cfcdisp end

 * SECTION 2 - Common and HVAC calculations
```

```
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Nominal Efficiency Oil Boiler

Background. The replacement of older, inefficient oil-fired boilers can save a significant portion of yearly oil heating costs. It is assumed that the buildings best suited for conversion are those that have oil-fired hot water boilers in the size range of 0.5 to 1.5 MBtu/hr.

Facility assumptions. This ECO applies to all buildings except family housing. It is assumed that a certain percentage of the boiler plants are hydronic and have an average size (see assumptions below). The larger boilers are replaced by two high-efficiency boilers with a rating of 40 percent of the original capacity. Seasonal efficiencies for the old and new plants are also given.

Uncited sources. This ECO follows the analysis for the Pulse Combustion (High Efficiency Gas Boiler) ECO. Telephone discussions with Roger McDonald, Researcher, Brookhaven National Laboratory, 24 February 1994.

Assumptions file.

```
REEP ECO REPORT                                        Page  1
07/08/94
```

ECO: Oil Nomeff Boiler

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	Oil Nomeff Boiler
UNIT	Unit	Boilers
ECOTYPE	Energy Opportunity Type	Heating/Cooling
PROGRAM	Rules File (Program) Name	oilboilr
CAPCOST	Capital Cost	5000.00
RECURCOST	Recurring Cost	0.00
ECONLIFE	Economic Life	15.00
DISCQTY	Discount Quantity	10.00
ASSUM01	ECO Assumption 01	Typ. Boiler Plant Size [MBtu/hr]
ASSUM01V	ECO Assumption 01 Value	1.55
ASSUM02	ECO Assumption 02	Typ. Replacement Boiler Size [M
ASSUM02V	ECO Assumption 02 Value	0.30
ASSUM03	ECO Assumption 03	% oil boilers < .35 MBtu/hr
ASSUM03V	ECO Assumption 03 Value	30.00
ASSUM04	ECO Assumption 04	% oil boilers .75 - 3.5 MBtu/hr
ASSUM04V	ECO Assumption 04 Value	24.00
ASSUM05	ECO Assumption 05	Seasonal Eff. of New Plants
ASSUM05V	ECO Assumption 05 Value	85.00
ASSUM06	ECO Assumption 06	Seasonal Eff. of Old Plants
ASSUM06V	ECO Assumption 06 Value	70.00

Rules file.

```
* This is the oilboilr.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xfulloahea = 0
         replace numecouni ;
            with 0
else
         replace numecouni ;
            with ( 1 - penfac ) * ( ( ( xohp7535con * xassum04v ;
                 / 100 + xohp75con * xassum03v / 100 ) * ;
                 ( xassum06v / 100 ) / (xassum02v * xfulloahea ) + ;
                 ( ( xohp7535cap * xassum04v / 100 + ;
                 xohp75cap * xassum03v / 100 ) * 2 / ;
                 xassum01v ) ) ) / 2
```

```
endif

* numecouni end

********** Select Project Size Factor *************

do comcalc0

********** Calculate adjusted initial cost **********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * xassum02v * xfulloahea * ;
         ( ( 100 / xassum06v ) - ( 100 / xassum05v ) )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start
```

```
replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with 0

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

  replace gasenesav ;
     with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

  replace oilenesav ;
     with heaenesav

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

  replace coaenesav ;
     with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end
```

```
********** Calculate Lbs. of CFC's displaced **********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Single Loop Digital Control (SLDC) Panels

Background. Control systems for HVAC systems in existing DOD buildings are typically commercial grade (low-bid) pneumatic systems. These pneumatic control systems are generally not properly operated and maintained for various reasons, not the least of which is the quality and maintainability of the system. As a result, the HVAC system in most buildings provides poor occupant comfort and wastes considerable energy. Installing standardized SLDC panels using "industrial" quality hardware and detailed commissioning and performance testing standards can significantly reduce the energy consumption of the facility while improving occupant comfort and reducing maintenance requirements.

Facility assumptions. The SLDC panels have been analyzed as being applicable to a certain percentage of six building types: Administrative, barracks, community, training, medical, and research and development (R&D). These building types were considered as candidates for this ECO. The estimates were based on the size and complexity of the buildings and whether or not they could be shut down at night. The following facility assumptions indicate how each facility type was characterized. Each facility type was analyzed based on its typical physical characteristics and energy consumption (Sliwinski et al., 1979).

Administrative Buildings		
Typical building size	15,000	Square Feet
Number of SLDC panels	1	
% of total admin space applicable	55	Percent
Heating load	18.97	Btu/SF/HDD
Cooling season electrical load	0.0512	kWh/SF
Noncooling season electrical load	0.0215	kWh/SF

Barracks		
Typical building size	45,600	Square Feet
Number of SLDC panels	3	
% of total barracks space applicable	40	Percent
Heating load	26.27	Btu/SF/HDD
Cooling electrical load	0.00127	kWh/SF/CDD
Base electrical load	0.0215	kWh/SF

Community Facility		
Typical building size	10,200	Square Feet
Number of SLDC panels	1	
% of total community space applicable	80	Percent
Heating load	22.97	Btu/SF/HDD
Cooling season electrical load	0.0684	kWh/SF
Noncooling season electrical load	0.0682	kWh/SF

Training Facility		
Typical building size	22,000	Square Feet
Number of SLDC panels	2	
% of total training space applicable	30	Percent
Heating load	18.97	Btu/SF/HDD
Cooling season electrical load	0.0512	kWh/SF
Noncooling season electrical load	0.0215	kWh/SF

Medical Facility		
Typical building size	16,000	Square Feet
Number of SLDC panels	1	
% of total medical space applicable	30	Percent
Heating load	24.31	Btu/SF/HDD
Cooling season electrical load	0.0557	kWh/SF
Noncooling season electrical load	0.0353	kWh/SF

R&D Facility		
Typical building size	36,000	Square Feet
Number of SLDC panels	3	
% of total R&D space applicable	80	Percent
Heating load	18.97	Btu/SF/HDD
Cooling season electrical load	0.0512	kWh/SF
Noncooling season electrical load	0.0215	kWh/SF

Typical building sizes were determined using Fort Hood data. Square footage values were calculated by dividing the total square footage of each building category by the number of buildings in that category, and then rounding the value to the nearest 100 sq ft. The percentages of applicable buildings were based on the relative square footage that fit the general size and characteristics desired for applying the ECO. Energy use factors for barracks and community facilities were developed using square footage mixes and percentages from Forts Hood, Carson, and Belvoir.

SLDC conclusions. SLDC panels have a significant potential for application in DOD buildings. The paybacks are quite short and the energy savings are large.

Assumptions file.

```
REEP ECO REPORT                                                  Page 1
09/01/94

ECO:  SLDC Panels

FIELD       DESCRIPTION                                           VALUE
-----------------------------------------------------------------------
ECO         Energy Opportunity                              SLDC Panels
UNIT        Unit                                                 Panels
ECOTYPE     Energy Opportunity Type                     Heating/Cooling
PROGRAM     Rules File (Program) Name                          singloop
CAPCOST     Capital Cost                                       12376.00
RECURCOST   Recurring Cost                                        -1.60
ECONLIFE    Economic Life                                         20.00
DISCQTY     Discount Quantity                                     20.00
```

ASSUM01	ECO Assumption 01	Barracks (%)
ASSUM01V	ECO Assumption 01 Value	40.00
ASSUM02	ECO Assumption 02	Training (%)
ASSUM02V	ECO Assumption 02 Value	30.00
ASSUM03	ECO Assumption 03	Medical (%)
ASSUM03V	ECO Assumption 03 Value	30.00
ASSUM04	ECO Assumption 04	R&D (%)
ASSUM04V	ECO Assumption 04 Value	80.00
ASSUM05	ECO Assumption 05	Community (%)
ASSUM05V	ECO Assumption 05 Value	80.00
ASSUM06	ECO Assumption 06	Administrative (%)
ASSUM06V	ECO Assumption 06 Value	55.00
ASSUM07	ECO Assumption 07	Heating Energy Saved (%)
ASSUM07V	ECO Assumption 07 Value	25.00
ASSUM08	ECO Assumption 08	Cooling Energy Saved (%)
ASSUM08V	ECO Assumption 08 Value	20.00
ASSUM09	ECO Assumption 09	Basic Electrical Saved (%)
ASSUM09V	ECO Assumption 09 Value	8.00

Rules file.

```
* This is the singloop.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with ( 1 - penfac ) * ( ( 2 * xassum02v / 100 * xtraare ;
            / 22 ) + ( 3 * xassum04v / 100 * xrdtare / 36 ) ;
            + ( xassum03v / 100 * xhosmedare / 16 ) + ;
            ( 1.25 * xassum06v / 100 * xadmare / 15 ) + ( 3 ;
            * xassum01v / 100 * xbarare / 45.6 ) + ( xassum05v ;
            / 100 * xcomfacare / 10.2 ) )

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start
```

```
replace inicos ;
   with xlocind * numecouni * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with xassum07v / 100000 * xhdd * ( ( xassum02v / 100 * ;
        xtraare * 18.97 ) + ( xassum04v / 100 * ;
        xrdtare * 18.97 ) + ( xassum03v / 100 * ;
        xhosmedare * 24.31 ) + ( xassum06v / 100  * ;
        xadmare * 18.97 ) + ( xassum01v / 100 * xbarare ;
        * 26.27 ) + ( xassum05v / 100 * xcomfacare * ;
        22.97 ) ) * ( 1 - penfac )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

if xaclogtst = 1
      replace cooenesav ;
         with ( ( xassum08v / 100 * xcdd * .001275 + xassum09v ;
              / 100 * ( 365 - xheaseaday - xcooseaday ) * ;
              .0152 ) * xassum01v / 100 * ;
                  3.412 * xbarare ) + ( xassum08v / 100 * xcooseaday * ;
                  3.412 * ( ( xassum02v / 100 * xtraare * ;
                  .0512 ) + ( xassum04v / 100 * xrdtare * ;
                  .0512 ) + ( xassum03v / 100 * xhosmedare ;
                  * .0557 ) + ( xassum06v / 100 * xadmare * ;
                  .0512 ) + ( xassum05v / 100 * xcomfacare * ;
                  .0684 ) ) ) + ( xassum09v / 100 * ( 365 - ;
                  xheaseaday ) * 3.412 * ( ( xassum02v / 100 ;
                  * xtraare * .0215 ) + ( xassum04v / 100 * ;
                  xrdtare * .0215 ) + ( xassum03v / 100 * ;
                  xhosmedare * .0353 ) + ( xassum06v / 100 ;
                  * xadmare * .0215 ) + ( xassum05v / 100 ;
                  * xcomfacare * .0662) ) ) * ( 1 - penfac )
else
      replace cooenesav ;
         with ( 365 - xheaseaday ) * xassum09v / 100 ;
              * 3.412 * ( ( xassum02v / 100 * ;
                  xtraare * .0215 ) + ( xassum04v / 100 * ;
              xrdtare * .0215 ) + ( xassum03v / 100 * ;
              xhosmedare * .0353 ) + ( xassum06v / 100 * ;
              xadmare * .0215 ) + ( xassum05v / 100 * ;
              xcomfacare * .0662 ) + ( xassum01v / 100 ;
```

```
                 * xbarare * .0152 ) ) * ( 1 - penfac )
endif

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end
********** calculate gas fuel saved **********

* gasenesav start

x = xghp35con + xghp7535con + xohp35con + xohp7535con + ;
    xchp35con + xchp7535con
if x = 0
      replace gasenesav ;
         with 0
else
      replace gasenesav ;
         with heaenesav * ( xghp35con + xghp7535con ) / ( ;
              xghp35con + xghp7535con + xohp35con + ;
              xohp7535con + xchp35con + xchp7535con )
endif

* gasenesav end

********** calculate oil fuel saved **********
```

```
* oilenesav start

x = xghp35con + xghp7535con + xohp35con + xohp7535con + ;
    xchp35con + xchp7535con
if x = 0
      replace oilenesav ;
         with 0
else
      replace oilenesav ;
         with heaenesav * ( xohp35con + xohp7535con ) / ( ;
              xghp35con + xghp7535con + xohp35con + ;
              xohp7535con + xchp35con + xchp7535con )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

x = xghp35con + xghp7535con + xohp35con + xohp7535con + ;
    xchp35con + xchp7535con
if x = 0
      replace coaenesav ;
         with 0
else
      replace coaenesav ;
         with heaenesav * ( xchp35con + xchp7535con ) / ( ;
              xghp35con + xghp7535con + xohp35con + ;
              xohp7535con + xchp35con + xchp7535con )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end
```

```
* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

*********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Ventilation Heat Recovery

Background. Ventilation heat recovery is the utilitization of heat energy that would otherwise be wasted. Waste heat is substituted for a portion of the heat energy that would normally be required for heating or cooling systems. Heat recovery conserves energy, reduces operating costs, and reduces peak loads when used with outdoor air. The model assumes that only the sensible heat is recovered through the use of a run-around coil system.

Facility assumptions. Application of ventilation heat recovery has been analyzed as being applicable to a certain percentage of six facility types: Administrative, barracks, community, training, medical, and R&D. These facilities were considered as candidates for this ECO. The following facility assumptions indicate how each facility type was characterized. Each type was analyzed based on its typical physical characteristics and energy consumption (Sliwinski et al., 1979).

<u>Administrative Buildings</u>

Typical building size (SF):	15,000
% of total admin space applicable:	50

Barracks

Typical building size (SF):	45,600
% of total Barracks space applicable:	33

Community Facility

Typical building size (SF):	10,200
% of total Comm'ty space applicable:	50

Training Facility

Typical building size (SF):	22,000
% of total training space applicable:	20

Medical Facility

Typical building size (SF):	16,000
% of total medical space applicable:	100

R&D Facility

Typical building size (SF):	36,000
% of total R&D space applicable:	80

Typical building sizes were determined using Fort Hood data. Square footage values were calculated by dividing the total square footage of each building category by the number of buildings in that category, and then rounding the value to the nearest 100 sq ft. The percentages of applicable buildings were based on the relative square footage that fit the general size and characteristics desired for applying the ECO. Energy use factors for barracks and community facilities were developed using square footage mixes and percentages from Forts Hood, Carson, and Belvoir.

Ventilation heat recovery algorithms.

$$N_{Units} = BT_{KSF} / TYP_{Size} \times PT_{Bldg} \times AP_{\%}$$

Heating Savings (MBtu/Yr) = $.2 \times BT_{KSF} \times Q_{HBT} \times HDD \times AP_{\%} / 1,000$
per building type per installation

Cooling Savings (MBtu/Yr) = $3.414 \times AP_{\%} \times BT_{KSF} \times (.2 \times Q_{CBT} \times CDD$
per building type per installation

Demand Savings (kW/Yr) = $(D_{FHU} / 5) \times AP_{\%} \times BT_{KSF} / TYP_{Size}$

where: N_{Units} = Number of units to be installed

BT_{KSF} = KSF of building type being analyzed

TYP_{Size} = Typical building size for category

PT_{Bldg} = Number of AHUs in typical building for category

$AP_{\%}$ = % of bldg. stock applicable for SLDC retrofit

Q_{HBT} = Building heating load for a specific type (Btu/SF/HDD)

HDD = Heating Degree Days (Degree F days)

CDD = Cooling Degree Days (Degree F days)

Ventilation heat recovery conclusions. Ventilation heat recovery systems have a potential for application in Army buildings. The paybacks are in the medium range and the energy savings moderate.

Assumptions file.

REEP ECO REPORT
09/01/94 Page 1

ECO: Ventilation Heat Recovery

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	Ventilation Heat Recovery
UNIT	Unit	Heat Exchs
ECOTYPE	Energy Opportunity Type	Heating/Cooling
PROGRAM	Rules File (Program) Name	ventheat
CAPCOST	Capital Cost	3000.00
RECURCOST	Recurring Cost	1.00
ECONLIFE	Economic Life	20.00
DISCQTY	Discount Quantity	40.00
ASSUM01	ECO Assumption 01	Barracks (%)
ASSUM01V	ECO Assumption 01 Value	33.00
ASSUM02	ECO Assumption 02	Training (%)
ASSUM02V	ECO Assumption 02 Value	20.00
ASSUM03	ECO Assumption 03	Medical (%)
ASSUM03V	ECO Assumption 03 Value	100.00
ASSUM04	ECO Assumption 04	R&D (%)
ASSUM04V	ECO Assumption 04 Value	80.00
ASSUM05	ECO Assumption 05	Community (%)

ASSUM05V	ECO Assumption 05 Value	50.00
ASSUM06	ECO Assumption 06	Administration (%)
ASSUM06V	ECO Assumption 06 Value	50.00
ASSUM07	ECO Assumption 07	AC COP
ASSUM07V	ECO Assumption 07 Value	3.00
ASSUM08	ECO Assumption 08	Efficiency of heat recovery (%)
ASSUM08V	ECO Assumption 08 Value	60.00
ASSUM09	ECO Assumption 09	Hours per vent operation
ASSUM09V	ECO Assumption 09 Value	12.00
ASSUM10	ECO Assumption 10	% locations applicable
ASSUM10V	ECO Assumption 10 Value	0.70

Rules file.

```
* This is the ventheat.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with ( 2 * xassum02v / 100 * xtraare / 22 ) + ( 3 * ;
        xassum04v / 100 * xrdtare / 36 ) + ( xassum03v ;
        / 100 * xhosmedare / 16 ) + ( 1.25 * xassum06v ;
        / 100 * xadmare / 15 ) + ( 3 * xassum01v / 100 ;
        * xbarare / 45.6 ) + ( xassum05v / 100 * ;
        xcomfacare / 10.2 ) * ( 1 - penfac ) * xassum10v

* numecouni end

********** Select Project Size Factor

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with xlocind * numecouni * xcapcost * prosizfac

* inicos end
```

```
********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with xassum08v / 100 * 2592 / 1000000 * ( 68 * ;
             xheaseaday - xhdd ) * ( ( ( xassum02v / 100 ) * ;
             (  xassum09v / 24) * xtraare ) + ( ( xassum04v ;
             / 100 ) * ( xassum09v / 24 ) * xrdtare ) + ;
             ( ( xassum03v / 100 ) * xhosmedare ) + ;
             ( ( xassum06v / 100 ) * ( xassum09v / 24 ) * ;
             xadmare ) + ( ( xassum01v / 100 ) * ( xassum09v ;
             / 24 ) * xbarare ) + ( xassum05v / 100 * ;
             ( xassum09v / 24 ) * xcomfacare ) ). * ;
             ( 1 - penfac )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

if xaclogtst = 1
      replace cooenesav ;
         with 108 * 5 * xassum08v / 100 * xsacdbh * ( ( ;
               xassum02v / 100 * xtraare ) + ( xassum04v / ;
               100 * xrdtare ) + ( xassum03v / 100 * ;
               xhosmedare ) + ( xassum06v / 100 * xadmare ;
               ) + ( xassum01v / 100 * xbarare ) + ( ;
               xassum05v / 100 * xcomfacare ) ) * ( 1 / ;
               1000 ) * ( 1 / 1000 ) * ( 1 - penfac )
else
      replace cooenesav ;
         with 0
endif

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav / xassum07v

* eleenesav end

********** calculate baseload demand saved **********
```

```
* basdemsav start

if cooenesav > 0
      replace basdemsav ;
         with numecouni * 1.5 * 540 /12000
else
      replace basdemsav ;
         with 0
endif

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
  with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

x = xghp35con + xghp7535con +xohp35con + xohp7535con ;
    + xchp35con + xchp7535con
if x = 0
      replace gasenesav ;
         with 0
else
      replace gasenesav ;
         with ( xghp35con + xghp7535con ) * xgascomeff / ;
            ((( xghp35con + xghp7535con ) * xgascomeff ) + ;
            (( xohp35con + xohp7535con ) * xoilcomeff ) + ;
            (( xchp35con + xchp7535con ) * xcoacomeff )) ;
            * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

x = xghp35con + xghp7535con +xohp35con + xohp7535con ;
    + xchp35con + xchp7535con
```

```
if x = 0
      replace oilenesav ;
         with 0
else
      replace oilenesav ;
         with ( xohp35con + xohp7535con ) * xoilcomeff / ;
            ((( xghp35con + xghp7535con ) * xgascomeff ) + ;
            (( xohp35con + xohp7535con ) * xoilcomeff ) + ;
            (( xchp35con + xchp7535con ) * xcoacomeff )) ;
            * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

x = xghp35con + xghp7535con +xohp35con + xohp7535con ;
    + xchp35con + xchp7535con
if x = 0
      replace coaenesav ;
         with 0
else
      replace coaenesav ;
         with ( xchp35con + xchp7535con ) * xcoacomeff / ;
            ((( xghp35con + xghp7535con ) * xgascomeff ) + ;
            (( xohp35con + xohp7535con ) * xoilcomeff ) + ;
            (( xchp35con + xchp7535con ) * xcoacomeff )) ;
            * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0
```

```
* cfcdisp end

* SECTION 2 - Common and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Lighting

Lighting Energy Conservation Opportunities

An installation uses about 20 to 30 percent of its electricity for lighting (Taylor and Dubravec, May 1990). Retrofitting lighting to more efficient systems could lead to substantial savings. This section of ECOs covers a variety of lighting retrofits, some dealing with the system itself and others controlling lighting. REEP assumes that the lighting system retrofits (4 ft fluorescent lighting, compact fluorescent lighting, etc.) are implemented before any controls are installed. In the case of constant level lighting, it is assumed that the retrofits are done at the same time to prevent excessive costs.

It can be estimated safely that 30 percent of the energy used for lighting can be saved by implementing a variety of lighting ECOs, which can translate to approximately 10 percent of an installation's electricity bill. Further savings can be expected by ensuring that lighting systems are optimized for efficiency. Checking areas to make sure they are not overlit will, in many cases, save even more energy. Ensuring that high intensity discharge (HID) lamps are replaced on a regular basis will provide better lighting because

many HID lamps have severe lamp lumen depreciation (they use the same amount of energy, yet provide half the light). Ensuring that lighting systems are maintained will also reap some benefits. For example, outdoor photocells default to the ON position when they fail and will allow lights to burn 24 hours per day until repaired. Well maintained systems will minimize such instances of unnecessary lighting during daylight hours.

As discussed in the two ECOs on compact fluorescent lighting and high wattage incandescent lighting, incandescent lighting is one of the least efficient ways to illuminate an area. Approximately 80 percent of the energy used is converted to heat (Rea 1993), not light (it is also an inefficient heating source). Savings of 50 to 75 percent can be realized for areas where incandescent lighting has been replaced.

An average single office may be lit by two 2-lamp fluorescent fixtures. To achieve the same illumination, the office would have to be lit by ten 100-Watt incandescent lamps. Table D5 shows the differences in cost for running each of three systems for 1 year. The general assumptions are 50 hours per week, 50 weeks per year, and $0.05/kWh.

Lighting also affects the heating and air conditioning systems in a building. A simplified method was used to estimate the effects that more efficient lighting technologies will have on the HVAC systems (R.A. Rundquist Associates). Unless noted, all the lighting ECOs use this method to estimate savings and costs due to less heat being generated by the lighting systems.

4-ft Fluorescent Lighting

Background: One often-instituted energy conservation retrofit involves the replacement of older magnetic ballasts and fluorescent lamps with new high-efficiency components. The replacement electronic ballasts and T8 lamps are designed to provide the same amount of light as the inefficient fixture, while using significantly less energy and improving the quality of the light provided. An important secondary benefit of this ECO is the reduction in heat dissipated from the fixture, thus reducing cooling loads. Heating loads, however, will increase due to the reduced heat output from the lighting system. Therefore, heating savings are indicated as a negative value in the ECO analysis.

Table D5. Annual energy costs for alternative lighting systems.

Lighting system	Wattage	Annual cost ($)
Electronic ballasts with T8 lamps	120	15.00
Energy efficient ballasts with T12 lamps	178	22.25
Incandescent lighting	1000	125.00

Ballast and fluorescent lamp characteristics. Pre- and post-retrofit lighting fixture characteristics had to be assumed to evaluate this ECO. Pre-retrofit characteristics represent a standard magnetic ballast and half 34 W energy saver rapid start (T-12) cool white lamps and half 40 W rapid start (T-12) cool white lamps (efficacy = 60 lumens/Watt). Post-retrofit characteristics represent an electronic ballast with 32 W, T-8, 3500K fluorescent lamps (efficacy = 90 lumens/Watt). Fixtures with four, three, and two lamps were retrofit with a two-lamp fixture and one lamp fixtures were retrofit with a one-lamp fixture. Since the general retrofit for four and three-lamp fixtures reduces the number of lamps, this retrofit should not be used in areas that do not have sufficient illumination. In many cases throughout the DOD, though, spaces are overlit, so this reduction should not cause any problems.

Facility assumptions. This ECO was applied to all areas of an installation, except for family housing. Fixture densities (sq ft/fixture) were derived from the raw data from Clanton Engineering's survey of 2 million sq ft at Fort Hood. Different densities were derived for each facility type to increase accuracy of the estimate. The details of the analysis can be seen in the 4ftfluor.prg program. The fluorescent fixtures analyzed by this ECO amount to 90 percent of the fluorescent fixtures on an installation. Therefore, a corrective factor was incorporated in the calculation for the number of fixtures that would be affected by this ECO.

Facility Type	Fixture Density (sqft/fixture)
Training	74
Maintenance and Production	133
Storage	542
Hospital and Medical	69
Administration	65
Unaccompanied Personnel Housing	138
Community	108
Research, Development, and Testing	86

When calculating the increase in heating demand, this ECO uses a multiplier for a perimeter area fraction. The fraction of area on the perimeter of a building is the fraction of a building's area within 15 feet of an outside wall. This is necessary since it was assumed that only that fraction of the building has a heat load that could be offset by heat generated by the lighting system. To arrive at this number, the dimensions of an average building on an installation was assumed to be 50 ft × 130 ft.

A diversity factor is used in the calculations accounts for office or area lights that are not operating at any given time due to vacations, absenteeism, meetings, etc. In this case,

the factor assumes that 10 percent of lights base-wide will be off at any given time during business hours.

Assumptions file.

```
REEP ECO REPORT                                              Page  1
07/12/94

ECO:  4' Fluorescent Ltng

FIELD        DESCRIPTION                                           VALUE
-----------------------------------------------------------------------
ECO          Energy Opportunity                       4' Fluorescent Ltng
UNIT         Unit                                                Fixtures
ECOTYPE      Energy Opportunity Type                             Lighting
PROGRAM      Rules File (Program) Name                           4ftfluor
CAPCOST      Capital Cost                                          136.14
RECURCOST    Recurring Cost                                         -1.50
ECONLIFE     Economic Life                                          15.00
DISCQTY      Discount Quantity                                     100.00
ASSUM01      ECO Assumption 01                      4 lamp original wattage
ASSUM01V     ECO Assumption 01 Value                               178.00
ASSUM02      ECO Assumption 02                      3 lamp original wattage
ASSUM02V     ECO Assumption 02 Value                               141.00
ASSUM03      ECO Assumption 03                      2 lamp original wattage
ASSUM03V     ECO Assumption 03 Value                                89.00
ASSUM04      ECO Assumption 04                      1 lamp original wattage
ASSUM04V     ECO Assumption 04 Value                                52.00
ASSUM05      ECO Assumption 05                   retrofit wattage for 4, 3, and
ASSUM05V     ECO Assumption 05 Value                                60.00
ASSUM06      ECO Assumption 06                  retrofit wattage for 1 lamp fix
ASSUM06V     ECO Assumption 06 Value                                30.00
ASSUM07      ECO Assumption 07                  percentage of fixtures with 4 l
ASSUM07V     ECO Assumption 07 Value                                22.00
ASSUM08      ECO Assumption 08                  percentage of fixtures with 3 l
ASSUM08V     ECO Assumption 08 Value                                28.00
ASSUM09      ECO Assumption 09                  percentage of fixtures with 2 l
ASSUM09V     ECO Assumption 09 Value                                44.00
ASSUM10      ECO Assumption 10                  percentage of fixtures with 1 l
ASSUM10V     ECO Assumption 10 Value                                 6.00
ASSUM11      ECO Assumption 11                  difference in cost for the 1 la
ASSUM11V     ECO Assumption 11 Value                                26.13
ASSUM12      ECO Assumption 12                               diversity factor
ASSUM12V     ECO Assumption 12 Value                                 0.90
ASSUM13      ECO Assumption 13                        annual hours of operation
ASSUM13V     ECO Assumption 13 Value                              3640.00
ASSUM14      ECO Assumption 14                     fraction of area on perimeter
ASSUM14V     ECO Assumption 14 Value                                 0.70
ASSUM15      ECO Assumption 15                                        A/C COP
ASSUM15V     ECO Assumption 15 Value                                 3.00
```

ASSUM16	ECO Assumption 16		
ASSUM16V	ECO Assumption 16 Value		0.00
ASSUM17	ECO Assumption 17		
ASSUM17V	ECO Assumption 17 Value		0.00
ASSUM18	ECO Assumption 18		
ASSUM18V	ECO Assumption 18 Value		0.00
ASSUM19	ECO Assumption 19	winter interior design temperat	
ASSUM19V	ECO Assumption 19 Value		68.00
ASSUM20	ECO Assumption 20	summer interior design temperat	
ASSUM20V	ECO Assumption 20 Value		78.00

Rules file.

```
* This is the 4ftfluor.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xassum01v = 0
  replace numecouni ;
     with 0
else
  replace numecouni ;
     with ( ( xtraare / 74 ) + ( xmaiproare / 133 ) + ;
           ( xstoare / 542 ) + ( xhosmedare / 69 ) + ;
           ( xadmare / 65 ) + ( xbarare / 138 ) + ;
           ( xcomfacare / 108 ) + ( xrdtare / 86 ) ) ;
           * 1000 * .9 * ( 1 - penfac )
endif

* numecouni end

******** Select Project Size Factor********

do comcalc0

******* Calculate Adjusted Initial Cost *******

* inicos start

replace inicos ;
   with numecouni * ( ( xcapcost * ( xassum07v + ;
         xassum08v + xassum09v )  / 100 + ;
         ( xcapcost - xassum11v ) * xassum10v / ;
```

```
          100 ) ) * xlocind * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with numecouni * ( ( xassum01v - xassum05v ) * ;
        xassum07v / 100 + ( xassum02v - xassum05v ) * ;
        xassum08v / 100 + ( xassum03v - xassum05v ) * ;
        xassum09v / 100 + ( xassum04v - xassum06v ) * ;
        xassum10v / 100 ) / 1000 * xassum12v

* basdemsav end

********** calculate summer demand saved ***********

* sumdemsav start

replace sumdemsav ;
   with basdemsav * xligcoofra / xassum15v * ;
        xaclogtst

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with -1 * basdemsav * xligheafra * xassum13v * 3412 / ;
        1000000 * xassum14v

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with ( basdemsav * xassum13v * xligcoofra * 3412 / ;
        1000000) / xassum15v * xaclogtst

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start
```

```
replace eleenesav ;
   with basdemsav * xassum13v * 3412 / 1000000 + ;
        cooenesav

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) * xgascomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) * xoilcomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
```

```
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) * xcoacomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

******* Calculate Lbs. of CFCs displaced *******

*cfcdisp start

replace cfcdisp ;
   with 0

*cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with cooenesav * xadjelecos
```

```
* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Compact Fluorescent Lighting

Background. Compact fluorescent lighting has steadily gained popularity as lamp costs decline and the color rendition of the lamps improves. Replacing incandescent lamps with compact fluorescents not only saves large amounts of energy at the light fixture itself, but it also reduces the cooling load on the HVAC system. Compact fluorescent lamps are used in this ECO to replace incandescent lamps that have wattages of 100 W or less. For wattages higher than 100 W, it is more reasonable to replace those lamps with a source that has a higher efficacy. As in the 4-ft fluorescent fixture, heating load increases, so heating savings are represented as a negative number in the ECO analysis.

Compact fluorescent characteristics. A diverse range of compact fluorescents are on the market. They range in wattages from 5 to 27 W and are available just as lamps that require a ballast to run or as self-ballasted with either a magnetic or electronic ballast and a standard Edison screw base for direct retrofit purposes. Costs and other general assumptions can be found under the compfluo.prg section in *Rules file* on p 303. The assumption is made that approximately 30 percent of the existing fixtures would not be able to use compact fluorescent lamps because of dimming requirements or size limitations. The retrofit used was replacement of an incandescent lamp with a self-ballasted compact fluorescent lamp with an electronic ballast since they are readily available and more efficient. The advantages of using an electronically ballasted compact fluorescent lamps are slightly lower wattage (1 or 2 W) and the electronic ballasts are significantly lighter. Table D6 shows the most common wattages of incandescent lamps and their proposed compact fluorescent replacements.

Facility assumptions. This ECO was applied in all facility types. The lamp densities (sqft/lamp) were derived from raw data of a survey of 2 million sq ft of Fort Hood facilities performed by Clanton Engineering. Since family housing was not included in this survey,

Table D6. Incandescent lamp wattage and proposed compact fluorescent replacement wattage.

Original wattage	50 Watt	60 Watt	75 Watt	100 Watt
Retrofit wattage	17	17	18	23
Number of lamps at this wattage (%)	27	32	24	17

an assumption was made that four compact fluorescent lamps could be used in an average family housing unit. To arrive at an estimated number of family housing units, it was assumed that an average family housing unit is 1500 sq ft. All other facility types were analyzed and the densities are listed below.

Facility Type	Lamp Density (sqft/lamp)
Training	600
Maintenance and Production	10150
Storage	615
Hospital and Medical	400
Administration	1400
Unaccompanied Personnel Housing	350
Community	370
Research, Development, and Testing	615

Since it was assumed that only a fraction of the building has a heat load that could be offset by heat generated by the lighting system, a number was determined for the fraction of the perimeter of a building's area within 15 ft of an outside wall.. To arrive at this number, the dimensions of an average building on an installation were assumed to be 50 ft × 130 ft. Then the area within 15 ft of an outside wall was determined.

The diversity factor used in these calculations accounts for office or area lights not being on due to vacations, absenteeism, meetings, etc. It essentially means that a certain percentage (10 percent in this case) of lamps will not be on at any given time.

Assumptions file.

```
REEP ECO REPORT                                                Page  1
07/12/94

ECO:  Compact Fluorescent Ltng

FIELD        DESCRIPTION
VALUE
---------------------------------------------------------------------
ECO          Energy Opportunity              Compact Fluorescent Ltng
UNIT         Unit                                               Lamps
ECOTYPE      Energy Opportunity Type                         Lighting
PROGRAM      Rules File (Program) Name                       compfluo
CAPCOST      Capital Cost                                       10.49
RECURCOST    Recurring Cost                                      0.00
ECONLIFE     Economic Life                                      15.00
DISCQTY      Discount Quantity                                 100.00
ASSUM01      ECO Assumption 01                average size of a FH unit
```

ASSUM01V	ECO Assumption 01 Value	1500.00
ASSUM02	ECO Assumption 02	opportunities per unit
ASSUM02V	ECO Assumption 02 Value	4.00
ASSUM03	ECO Assumption 03	Annual hours of operation
ASSUM03V	ECO Assumption 03 Value	2600.00
ASSUM04	ECO Assumption 04	wattage saved by retrofitting a
ASSUM04V	ECO Assumption 04 Value	57.00
ASSUM05	ECO Assumption 05	fraction of area on perimeter
ASSUM05V	ECO Assumption 05 Value	0.70
ASSUM06	ECO Assumption 06	
ASSUM06V	ECO Assumption 06 Value	0.00
ASSUM07	ECO Assumption 07	
ASSUM07V	ECO Assumption 07 Value	0.00
ASSUM08	ECO Assumption 08	
ASSUM08V	ECO Assumption 08 Value	0.00
ASSUM09	ECO Assumption 09	summer interior design temperat
ASSUM09V	ECO Assumption 09 Value	78.00
ASSUM10	ECO Assumption 10	winter interior design temperat
ASSUM10V	ECO Assumption 10 Value	68.00
ASSUM11	ECO Assumption 11	A/C COP
ASSUM11V	ECO Assumption 11 Value	3.00
ASSUM12	ECO Assumption 12	percentage of 50 watt lamps
ASSUM12V	ECO Assumption 12 Value	27.00
ASSUM13	ECO Assumption 13	percentage of 60 watt lamps
ASSUM13V	ECO Assumption 13 Value	32.00
ASSUM14	ECO Assumption 14	percentage of 75 watt lamps
ASSUM14V	ECO Assumption 14 Value	24.00
ASSUM15	ECO Assumption 15	percentage of 100 watt lamps
ASSUM15V	ECO Assumption 15 Value	17.00
ASSUM16	ECO Assumption 16	wattage saved by retrofitting a
ASSUM16V	ECO Assumption 16 Value	33.00
ASSUM17	ECO Assumption 17	wattage saved by retrofitting a
ASSUM17V	ECO Assumption 17 Value	43.00
ASSUM18	ECO Assumption 18	wattage saved by retrofitting a
ASSUM18V	ECO Assumption 18 Value	77.00
ASSUM19	ECO Assumption 19	percentage of fixtures that can
ASSUM19V	ECO Assumption 19 Value	30.00
ASSUM20	ECO Assumption 20	diversity factor
ASSUM20V	ECO Assumption 20 Value	0.90

Rules file.

```
* This is the compfluo.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********
```

```
* numecouni start

replace numecouni ;
   with ( ( ( ( xtraare / 600 ) + ( xmaiproare / 10150 ) + ;
         ( xhosmedare / 400 ) + ( xadmare / 1400 ) + ;
         ( xbarare / 350 ) + ( xcomfacare / 370 ) + ;
         ( xstoare / 615 ) + ( xrdtare / 615 ) ) * ;
         ( 1 - xassum19v / 100 ) ) + ( xfamhouare / ;
        xassum01v * xassum02v ) ) * 1000 * ( 1 - ;
        penfac )

* numecouni end

********* Select Project Size Factor **********

do comcalc0

********** Calculate Adjusted Initial Cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with numecouni * ( ( xassum16v / 1000 * xassum12v / ;
        100 ) + ( xassum17v / 1000 * xassum13v / 100 ) + ;
        ( xassum04v / 1000 * xassum14v / 100 ) + ;
        ( xassum18v / 1000 * xassum15v / 100 ) ) * xassum20v

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
   with basdemsav * xligcoofra / xassum11v * ;
        xaclogtst

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start
```

```
replace heaenesav ;
   with -1 * basdemsav * xligheafra * xassum03v * 3412 / ;
        1000000 * xassum05v

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with ( basdemsav * xassum03v * xligcoofra * 3412 / ;
        1000000 ) / xassum11v * xaclogtst

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with basdemsav * xassum03v * 3412 / 1000000 + ;
        cooenesav

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) * xgascomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
```

```
    replace oilenesav ;
       with 0
  else
    replace oilenesav ;
       with ( xohp35con + xohp7535con + xohp75con ) * xoilcomeff / ;
          ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
           (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
           (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
           * heaenesav / ( xoilcomeff / 100 )
  endif

  * oilenesav end

  ********** calculate coal fuel saved **********

  * coaenesav start

  zcheck = xchp35con + xchp7535con + xchp75con
  if zcheck = 0
    replace coaenesav ;
       with 0
  else
    replace coaenesav ;
       with ( xchp35con + xchp7535con + xchp75con ) * xcoacomeff / ;
          ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
           (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
           (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
           * heaenesav / ( xcoacomeff / 100 )
  endif

  * coaenesav end

  ********** calculate water saved **********

  * watvolsav start

  replace watvolsav ;
     with 0

  * watvolsav end

  ******* Calculate Lbs. of CFCs displaced *******

  *cfcdisp start

  replace cfcdisp ;
     with 0

  *cfcdisp end

  * SECTION 2 - Common calculations and HVAC calculations
```

```
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with cooenesav * xadjelecos

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Constant-Level Lighting

Background. Available technology will sense the amount of illumination in a space and dim or brighten the lights accordingly. This technology is called constant-level lighting because it maintains a preset level of illumination. The system saves energy in spaces open to outside light by allowing natural daylight to provide the lighting. Constant-level lighting also saves energy in interior spaces by compensating for lamp lumen depreciation. By using a constant-level lighting system, illumination in a space can be maintained throughout the life of the lighting system, dimming the lighting when the lamps are new and dimming less as depreciation increases. While saving energy, the quality of the lighting is improved.

System characteristics. The constant-level lighting system consists of a controller and a dimmable electronic ballast. Since dimmable electronic ballasts are significantly more expensive than regular electronic ballasts, this retrofit is not economical unless done at the same time as a general lighting retrofit (installation of new ballasts or a new lighting system). Therefore, the cost analysis for this retrofit includes only the cost of the controller and the marginal cost of using a dimmable ballast rather than using a regular electronic ballast.

The controller was estimated to save about 30 percent of the energy that the lighting system would otherwise use. It was also assumed that each controller would be controlling two 2-lamp fixtures totaling 120 W. If the system controls more than that, it would affect the economics positively.

Facility assumptions. This ECO was applied only to administrative areas on an installation. It was assumed that 40 percent of the spaces in these areas would have sufficient natural lighting that the savings from the system would be at least 30 percent. A diversity factor of 10 percent was assumed as it was in most of the lighting ECOs.

Assumptions file.

```
REEP ECO REPORT                                                Page  1
07/12/94

ECO:  Constant Level Lighting

FIELD      DESCRIPTION                                           VALUE
----------------------------------------------------------------------
ECO        Energy Opportunity                  Constant Level Lighting
UNIT       Unit                                               Contrllrs
ECOTYPE    Energy Opportunity Type                             Lighting
PROGRAM    Rules File (Program) Name                           consleve
CAPCOST    Capital Cost                                          130.00
RECURCOST  Recurring Cost                                          0.00
ECONLIFE   Economic Life                                          15.00
DISCQTY    Discount Quantity                                     100.00
ASSUM01    ECO Assumption 01                      Square feet / office
ASSUM01V   ECO Assumption 01 Value                               120.00
ASSUM02    ECO Assumption 02                     Floor area affected (%)
ASSUM02V   ECO Assumption 02 Value                                40.00
ASSUM03    ECO Assumption 03                 Annual hours of operation
ASSUM03V   ECO Assumption 03 Value                              2600.00
ASSUM04    ECO Assumption 04
ASSUM04V   ECO Assumption 04 Value                                 0.00
ASSUM05    ECO Assumption 05
ASSUM05V   ECO Assumption 05 Value                                 0.00
ASSUM06    ECO Assumption 06
ASSUM06V   ECO Assumption 06 Value                                 0.00
ASSUM07    ECO Assumption 07
ASSUM07V   ECO Assumption 07 Value                                 0.00
ASSUM08    ECO Assumption 08
ASSUM08V   ECO Assumption 08 Value                                 0.00
ASSUM09    ECO Assumption 09                                    A/C COP
ASSUM09V   ECO Assumption 09 Value                                 3.00
ASSUM10    ECO Assumption 10                           Diversity Factor
ASSUM10V   ECO Assumption 10 Value                                 0.90
ASSUM11    ECO Assumption 11                         Wattage controlled
```

```
ASSUM11V    ECO Assumption 11 Value                                120.00
ASSUM12     ECO Assumption 12        % reduction in wattage due to c
ASSUM12V    ECO Assumption 12 Value                                 30.00
```

Rules file.

```
* This is the consleve.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with xadmare * 1000 * ( xassum02v / 100 ) / xassum01v ;
        * ( 1 - penfac )

* numecouni end

*********** Select Project Size Factor ************

do comcalc0

********** Calculate Adjusted Initial Cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with numecouni * ( xassum11v / 1000 ) * ( xassum12v / ;
        100 ) * xassum10v

* basdemsav end
********** calculate summer demand saved ***********

* sumdemsav start
```

```
replace sumdemsav ;
   with basdemsav * xligcoofra / xassum09v * xaclogtst

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with -1 * basdemsav * xligheafra * xassum03v * ;
        3412 / 1000000

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with ( basdemsav * xassum03v * xligcoofra * 3412 / ;

                  1000000 ) / xassum09v * xaclogtst

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with (basdemsav * xassum03v * 3412 / 1000000 ) + ;
        cooenesav

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) * xgascomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xgascomeff / 100 )
```

```
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) * xoilcomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) * xcoacomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end
```

```
******* Calculate Lbs. of CFCs displaced *******

*cfcdisp start

replace cfcdisp ;
   with 0

*cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with cooenesav * xadjelecos

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Exit Lighting Retrofit

Background. Almost every nonresidential building has exit signs indicating paths of egress. Observed individually, these fixtures consume only a moderate amount of energy. However, observed globally, these lighting fixtures consume a phenomenal amount of energy since they run 24 hours per day, 365 days per year. Numerous retrofit options are available for exit lights.

Exit lighting characteristics. Most exit signs in older facilities contain two 20- to 25- W incandescent lamps. This ECO retrofits the existing lamps with a light emitting diode (LED) retrofit kit that has a double row of LEDs and attaches to either side of the interior of an existing exit sign. The kits are available in a variety of connections,

including hard-wired. They provide low energy use, long life (they have a 25-year warranty), and eliminate the need for exit sign maintenance. Other retrofits are possible (i.e., new LED exit signs, no energy exit sign fixtures, electroluminescent exit sign fixtures and compact fluorescent exit sign fixtures), but, unless a new fixture retrofit is desired, the LED retrofit kits are economical and the easiest to implement.

Facility assumptions. This ECO was applied to training, hospital, medical, administration, community, and barracks type facilities. The analysis is similar to the calculations used in the 4-ft fluorescent retrofit as well as the compact fluorescent retrofit.

Assumptions file.

REEP ECO REPORT Page 1
07/12/94

ECO: Exit Lighting

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	Exit Lighting
UNIT	Unit	Fixtures
ECOTYPE	Energy Opportunity Type	Lighting
PROGRAM	Rules File (Program) Name	exitligh
CAPCOST	Capital Cost	50.00
RECURCOST	Recurring Cost	-75.00
ECONLIFE	Economic Life	15.00
DISCQTY	Discount Quantity	100.00
ASSUM01	ECO Assumption 01	Square feet per fixture
ASSUM01V	ECO Assumption 01 Value	1500.00
ASSUM02	ECO Assumption 02	Annual hours of operation
ASSUM02V	ECO Assumption 02 Value	8760.00
ASSUM03	ECO Assumption 03	Fraction of area on perimeter
ASSUM03V	ECO Assumption 03 Value	0.70
ASSUM04	ECO Assumption 04	
ASSUM04V	ECO Assumption 04 Value	0.00
ASSUM05	ECO Assumption 05	
ASSUM05V	ECO Assumption 05 Value	0.00
ASSUM06	ECO Assumption 06	
ASSUM06V	ECO Assumption 06 Value	0.00
ASSUM07	ECO Assumption 07	
ASSUM07V	ECO Assumption 07 Value	0.00
ASSUM08	ECO Assumption 08	A/C COP
ASSUM08V	ECO Assumption 08 Value	3.00
ASSUM09	ECO Assumption 09	
ASSUM09V	ECO Assumption 09 Value	0.00
ASSUM10	ECO Assumption 10	Existing fixture wattage
ASSUM10V	ECO Assumption 10 Value	40.00

ASSUM11	ECO Assumption 11	Retrofit fixture wattage
ASSUM11V	ECO Assumption 11 Value	4.00

Rules file.

```
* This is the exitligh.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xassum01v = 0
  replace numecouni ;
     with 0
else
  replace numecouni ;
     with ( xtraare + xrdtare + xhosmedare + xadmare + ;
          xbarare + xcomfacare ) * 1000 / xassum01v * ;
          (1 - penfac )
endif

* numecouni end

******** Select Project Size Factor *******

do comcalc0

********** Calculate Adjusted Initial Cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with numecouni * ( xassum10v - xassum11v ) / 1000
```

```
* basdemsav end

********** calculate summer demand saved ***********

* sumdemsav start

replace sumdemsav ;
   with ( basdemsav / xassum08v ) * xaclogtst * ;
        xligcoofra

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with -1 * basdemsav * xligheafra * xassum02v * ;
        3412 / 1000000 * xassum03v

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with ( basdemsav * xassum02v * xligcoofra * ;
        3412 / 1000000 ) / xassum08v * xaclogtst

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with basdemsav * xassum02v * 3412 / 1000000 + ;
        cooenesav

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
```

```
    with 0
else
  replace gasenesav ;
    with ( xghp35con + xghp7535con + xghp75con ) * xgascomeff / ;
       ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
        (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
        (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
        * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
    with 0
else
  replace oilenesav ;
    with ( xohp35con + xohp7535con + xohp75con ) * xoilcomeff / ;
       ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
        (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
        (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
        * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
    with 0
else
  replace coaenesav ;
    with ( xchp35con + xchp7535con + xchp75con ) * xcoacomeff / ;
       ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
        (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
        (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
        * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end
```

```
********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

******* Calculate Lbs. of CFCs displaced *******

*cfcdisp start

replace cfcdisp ;
   with 0

*cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with cooenesav * xadjelecos

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Replace Mercury Vapor With High Pressure Sodium Lights

Background. Developed during the 1930s, mercury vapor lamps were frequently used in warehousing, storage, and maintenance facilities. Their efficacy was superior to that of other lighting available at the time, and life expectancies were much higher. Developed more recently, the high pressure sodium lights have even greater efficacies than mercury vapor lamps, and they have similar life expectancies.

High pressure sodium lighting characteristics. Since high pressure sodium lighting has higher efficacies than mercury vapor lamps, it is possible to replace a mercury vapor lamp with a high pressure sodium lamp of lower wattage while maintaining the same illuminance. After the lamp and ballast are replaced, the wattage drop is approximately 35 percent.

There are high pressure sodium lamps that will run on mercury vapor ballasts, but they are meant to work on ballasts that have been designed for comparable wattages. Therefore, implementation of this would yield marginal energy savings but illuminance would increase substantially. This application may be good in some instances, but REEP retrofits aim to maintain sufficient illumination while maximizing energy savings.

In this ECO, the existing mercury vapor wattage is assumed to be 400 W (455 W with the ballast losses) and the retrofit wattage is assumed to be 250 W (300 W with ballast losses).

Facility assumptions. This ECO was applied to training, maintenance and production, storage, and community facilities. From the survey data from Fort Hood, it was established that these areas all use significant amounts of HID lighting. Few mercury vapor lamps were found in the survey, and most of those were found in community facilities. This ECO was written so that buildings containing HID lighting would be included, but the square footage affected was minimized so that the numbers of opportunities would not be too high. Many spaces that originally contained mercury vapor lighting have already been retrofitted to more efficient systems, but it is recommended that any spaces that contain HID lighting be checked for mercury vapor lighting.

Because of the variety of facilities that are included in this ECO, lighting/HVAC interaction was not included in the analysis. Spaces such as community and training facilities that are air conditioned will actually have higher energy savings. This added savings is because the lighting generates less heat, thereby lowering the cooling load.

When retrofitting these types of areas, higher savings and shorter paybacks should be expected.

Assumption file.

```
REEP ECO REPORT                                              Page  1
07/12/94

ECO:  High Pressure Sodium Lghts

FIELD      DESCRIPTION                                         VALUE
--------------------------------------------------------------------
ECO        Energy Opportunity            High Pressure Sodium Lghts
UNIT       Unit                                                Lamps
ECOTYPE    Energy Opportunity Type                          Lighting
PROGRAM    Rules File (Program) Name                        sodilamp
CAPCOST    Capital Cost                                       200.00
RECURCOST  Recurring Cost                                       0.00
ECONLIFE   Economic Life                                       15.00
DISCQTY    Discount Quantity                                  100.00
ASSUM01    ECO Assumption 01                Applicable buildings (%)
ASSUM01V   ECO Assumption 01 Value                             40.00
ASSUM02    ECO Assumption 02                   Square feet / fixture
ASSUM02V   ECO Assumption 02 Value                            330.00
ASSUM03    ECO Assumption 03                  Floor area affected (%)
ASSUM03V   ECO Assumption 03 Value                             10.00
ASSUM04    ECO Assumption 04               Annual hours of operation
ASSUM04V   ECO Assumption 04 Value                           2600.00
ASSUM05    ECO Assumption 05               Existing MV fixture wattage
ASSUM05V   ECO Assumption 05 Value                            455.00
ASSUM06    ECO Assumption 06              Retrofit HPS fixture wattage
ASSUM06V   ECO Assumption 06 Value                            300.00
```

Rules file.

```
* This is the sodilamp.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with ( xtraare + xcomfacare + xmaiproare + ;
```

```
        xstoare ) * 1000 * ( xassum01v / 100 ) * ;
        ( xassum03v / 100 ) / xassum02v * ( 1 - ;
        penfac )

* numecouni end

********Select Project Size Factor ********

do comcalc0

********** Calculate Adjusted Initial Cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with numecouni * ( xassum05v - xassum06v ) ;
        / 1000

* basdemsav end

*********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********
```

```
* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with basdemsav * xassum04v * 3412 / 1000000

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
     with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
     with 0


* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
     with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
```

```
   with 0

* watvolsav end

******* Calculate Lbs. of CFCs displaced *******

*cfcdisp start

replace cfcdisp ;
   with 0

*cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

High Wattage Incandescent Replacement

Background. Incandescent lighting is one of the simplest and most versatile lighting systems to implement because no ballasts are required. It is the least expensive lighting system to install, but it is also the least efficient lighting system used today. Because of the low initial cost and ease of installation, fluorescent lighting was commonly used in many areas. It is still used, almost exclusively, in residential applica-

tions. Less than 15 percent of the energy used by an incandescent lamp is converted to visible light. The rest is converted to heat. This ECO proposes two different retrofits to replace the majority of the high wattage (greater than or equal to 150 W) incandescent lamps: fluorescent lighting and metal halide lighting. Compact fluorescent lamps cannot provide enough light to replace these lamps. Two different systems are used so the majority of the many applications in which incandescent lamps are used could be covered. The retrofits achieve significant energy savings while maintaining equivalent light output and a high color rendition.

Retrofit characteristics. The lighting applications of high wattage incandescent lamps were broken into two large groups: general area illumination and downlighting/spotlighting. By looking at Fort Hood survey data specifying fixture types, it was determined that the two groups covered the majority of the applications.

Fluorescent lighting was chosen to replace the incandescent fixtures that provided general illumination. Specifically, T8 lamps and electronic ballasts are recommended in this retrofit to ensure that the color rendition does not suffer significantly. By replacing the incandescent lighting with the fluorescent system, energy costs are cut by approximately 75 percent. This ECO uses a different retrofit for each different incandescent wattage to ensure that energy savings estimates are accurate and that illumination levels are maintained. Table D7 lists the retrofits for each of the incandescent lamp wattages. The wattages listed are for the whole system, including ballasts.

Metal halide lighting was chosen to replace the incandescent lamps used in downlights and spotlights. By implementing this part of the retrofit, energy costs are reduced by approximately 50 percent. Metal halide lamps provide good color rendition and have a color similar to that of the fluorescent lamps proposed by this ECO. As in the fluorescent system replacement, different sizes of metal halide lamps are recommended for

Table D7. Metal halide lamp wattage and proposed compact fluorescent replacement wattage.

Original lamp wattage	Fluorescent replacement	MH replacement	% of lamps at this wattage
150	1 lamp T8 system (30 watts)	75 watts (lamp wattage is 50W)	37
200	2 lamp T8 system (60 watts)	95 watts (lamp wattage is 70W)	25
300	3 lamp T8 system (90 watts)	125 watts (lamp wattage is 100W)	35
400	no retrofit for this	175 watts (lamp wattage is 150W)	3

each wattage to be replaced, and the wattages listed are for the whole system, including ballasts. The lamp wattages are provided in parentheses.

Facility assumptions. This ECO was applied to all facility types, excluding family housing. The lamp densities were derived from raw data of a survey of 2 million sq ft at Fort Hood performed by Clanton Engineering. Different densities were derived for each facility type to increase the accuracy of the estimate. It was estimated that 10 percent of the fixture count could not be retrofitted with either the fluorescent or metal halide systems for various reasons. The estimated number of ECO units reflects this assumption. The hiwatinc.prg program shows details of the analysis.

Facility Type	Fixture Density (sqft/fixt)
Training	3560
Maintenance and Production	5880
Storage	1360
Hospital and Medical	12950
Administration	4350
Unaccompanied Personnel Housing	21770
Community	690
Research, Development, and Testing	3410

Assumptions file.

```
REEP ECO REPORT                                                Page   1
07/12/94

ECO:  High wattage incand replcmnt

FIELD      DESCRIPTION                                          VALUE
-------------------------------------------------------------------------
ECO        Energy Opportunity                High wattage incand replcmnt
UNIT       Unit                                                  Fixtures
ECOTYPE    Energy Opportunity Type                               Lighting
PROGRAM    Rules File (Program) Name                             hiwatinc
CAPCOST    Capital Cost                                            300.00
RECURCOST  Recurring Cost                                            0.00
ECONLIFE   Economic Life                                            15.00
DISCQTY    Discount Quantity                                       100.00
ASSUM01    ECO Assumption 01                    annual hours of operation
ASSUM01V   ECO Assumption 01 Value                                2600.00
ASSUM02    ECO Assumption 02               watts saved by replacing 150W w
ASSUM02V   ECO Assumption 02 Value                                 120.00
ASSUM03    ECO Assumption 03                wattage saved by replacing 150W
ASSUM03V   ECO Assumption 03 Value                                  80.00
ASSUM04    ECO Assumption 04               watts saved by replacing 200W w
```

ASSUM04V	ECO Assumption 04 Value	140.00
ASSUM05	ECO Assumption 05	watts saved by replacing 200W w
ASSUM05V	ECO Assumption 05 Value	105.00
ASSUM06	ECO Assumption 06	watts saved by replacing 300W w
ASSUM06V	ECO Assumption 06 Value	210.00
ASSUM07	ECO Assumption 07	watts saved by replacing 300W w
ASSUM07V	ECO Assumption 07 Value	175.00
ASSUM08	ECO Assumption 08	watts saved by replacing 400W w
ASSUM08V	ECO Assumption 08 Value	185.00
ASSUM09	ECO Assumption 09	% of fixtures retrofitted to fl
ASSUM09V	ECO Assumption 09 Value	50.00
ASSUM10	ECO Assumption 10	diversity factor
ASSUM10V	ECO Assumption 10 Value	0.90
ASSUM11	ECO Assumption 11	fraction of area on perimeter
ASSUM11V	ECO Assumption 11 Value	0.70
ASSUM12	ECO Assumption 12	A/C COP
ASSUM12V	ECO Assumption 12 Value	3.00
ASSUM13	ECO Assumption 13	
ASSUM13V	ECO Assumption 13 Value	0.00
ASSUM14	ECO Assumption 14	
ASSUM14V	ECO Assumption 14 Value	0.00
ASSUM15	ECO Assumption 15	
ASSUM15V	ECO Assumption 15 Value	0.00
ASSUM16	ECO Assumption 16	winter interior design temperat
ASSUM16V	ECO Assumption 16 Value	68.00
ASSUM17	ECO Assumption 17	summer interior design temperat
ASSUM17V	ECO Assumption 17 Value	78.00
ASSUM18	ECO Assumption 18	basic cost of fluorescent retro
ASSUM18V	ECO Assumption 18 Value	136.14

Rules file.

```
* This is the hiwatinc.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with ( ( xtraare / 3560 ) + ( xmaiproare / 5880 ) + ;
        ( xstoare / 1360 ) + ( xhosmedare / 12950 ) + ;
        ( xadmare / 4350 ) + ( xbarare / 21770 ) + ;
        ( xcomfacare / 690 ) + ( xrdtare / 3410 ) ) ;
        * 1000 * .9 * ( 1 - penfac )
```

```
* numecouni end

*********Select Project Size Factor **********

do comcalc0

******* Calculate Adjusted Initial Cost **********

* inicos start

replace inicos ;
   with ( ( numecouni * xcapcost * ( 1 - xassum09v / ;
        100 ) ) + ( numecouni * xassum18v * xassum09v / ;
        100 ) ) * xlocind * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with numecouni * ( ( xassum02v / 1000 * xassum09v / ;
        100 * .37 ) + ( xassum03v / 1000 * ( 1 - ;
        xassum09v / 100) * .37 ) + ( xassum04v / 1000 * ;
        xassum09v / 100 * .25 ) + ( xassum05v / 1000 * ;
        ( 1 - xassum09v / 100 ) * .25 ) + ( xassum06v / ;
        1000 * xassum09v / 100 * .35 ) + ( xassum07v / ;
        1000 * ( 1 - xassum09v / 100 ) * .35 ) + ;
        ( xassum08v / 1000 * .03 ) )

* basdemsav end

*********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
   with basdemsav / xassum12v * xaclogtst * xligcoofra

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with -1 * basdemsav * xligheafra * xassum01v * 3412 / ;
        1000000 * xassum11v
```

```
* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with ( basdemsav * xassum01v * xligcoofra * 3412 / ;
        1000000) / xassum12v * xaclogtst

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with basdemsav * xassum01v * 3412 / 1000000 + ;
        cooenesav

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) ;
         * xgascomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) ;
         * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) ;
         * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) ;
         * xcoacomeff )) ;
         * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start
```

```
zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) ;
         * xoilcomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) ;
         * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) ;
         * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) ;
         * xcoacomeff )) ;
         * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) ;
         * xcoacomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) ;
         * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) ;
         * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) ;
         * xcoacomeff )) ;
         * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0
```

```
* watvolsav end

******* Calculate Lbs. of CFCs displaced *******

*cfcdisp start

replace cfcdisp ;
   with 0

*cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with cooenesav * xadjelecos

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Occupancy Sensors

Background. Occupancy sensors turn off lights in unoccupied spaces. Simple payback of these units can range from a few months to a few years, depending on the occupancy characteristics and lighting load of the space being controlled. An additional benefit of a reduced lighting load is the accompanying reduction in cooling loads.

There are two main types of occupancy sensors: infrared and ultrasonic. Infrared sensors detect changes in the temperature profile in a room and require direct views

of where people would be located in a room. Ultrasonic sensors emit an ultrasonic wave and sense changes in the reflected wave. Ultrasonic sensors can sense changes behind partitions if located correctly. When preparing to install occupancy sensors, it is important to consider which type of sensor would work best in a room.

Occupancy sensor characteristics. This ECO analysis incorporated two occupancy sensors: a ceiling-mounted sensor for large areas and a wall-mounted sensor for small offices. Each sensor has different costs, loads, and savings associated with it, as Table D8 shows. If the controlled load were greater and the reduction in on-time were the same, energy savings would be greater, thereby shortening the simple payback.

Facility assumptions. This ECO was applied to training, hospital, medical, administrative, and community type facilities. No credit was taken for demand reduction, since the reduction in load cannot be guaranteed to occur during peak hours. Credit was taken for reduction in cooling loads, however. Assumptions were also made regarding how much area a sensor would cover (Table D9). These assumptions were used to estimate the number of possible opportunities in which the sensors could be used.

The number of ECO units reflects the number of occupancy sensors that can be used at the installation. This analysis does not provide separate numbers for ceiling- and wall-mounted sensors. Those numbers would have to be calculated by hand. When viewing the numerical results while in REEP, the numbers and equations used to calculate the number of ECO units can be accessed. In the calculation, the number of ceiling- and wall-mounted sensors has been calculated, but no final figure has been given. While looking at this calculation, the numbers can be figured using the formula that the ECO used.

Table D8. Cost comparison of ceiling- and wall-mounted sensors.

	Wall-mounted sensor	Ceiling-mounted sensor
Wattage controlled by sensor	120	420
Square foot coverage by sensor	120	500
Installed cost of sensor	60	120
Percent reduction in on-time	30	20

Table D9. Floor area affected by ceiling- and wall-mounted sensors.

	Wall-mounted sensor	Ceiling-mounted sensor
% of floor area affected by sensor	15	34

Assumptions file.

```
REEP ECO REPORT                                              Page  1
07/12/94

ECO:  Occupancy Sensor

FIELD        DESCRIPTION                                         VALUE
-----------------------------------------------------------------------
ECO          Energy Opportunity                       Occupancy Sensor
UNIT         Unit                                              Sensors
ECOTYPE      Energy Opportunity Type                          Lighting
PROGRAM      Rules File (Program) Name                        occusens
CAPCOST      Capital Cost                                       120.00
RECURCOST    Recurring Cost                                       0.00
ECONLIFE     Economic Life                                       15.00
DISCQTY      Discount Quantity                                  100.00
ASSUM01      ECO Assumption 01         % floor area affected by wall s
ASSUM01V     ECO Assumption 01 Value                             15.00
ASSUM02      ECO Assumption 02         % floor area affected by ceilin
ASSUM02V     ECO Assumption 02 Value                             34.00
ASSUM03      ECO Assumption 03              annual hours of operation
ASSUM03V     ECO Assumption 03 Value                           2600.00
ASSUM04      ECO Assumption 04         % of capcost that wall sensor c
ASSUM04V     ECO Assumption 04 Value                             50.00
ASSUM05      ECO Assumption 05           fraction of area on perimeter
ASSUM05V     ECO Assumption 05 Value                              0.50
ASSUM06      ECO Assumption 06
ASSUM06V     ECO Assumption 06 Value                              0.00
ASSUM07      ECO Assumption 07
ASSUM07V     ECO Assumption 07 Value                              0.00
ASSUM08      ECO Assumption 08                                 A/C COP
ASSUM08V     ECO Assumption 08 Value                              3.00
ASSUM09      ECO Assumption 09          wall sensor controlled wattage
ASSUM09V     ECO Assumption 09 Value                            120.00
ASSUM10      ECO Assumption 10         ceiling sensor controlled watta
ASSUM10V     ECO Assumption 10 Value                            420.00
ASSUM11      ECO Assumption 11         square foot coverage per ceilin
ASSUM11V     ECO Assumption 11 Value                            500.00
ASSUM12      ECO Assumption 12         % reduction of on-time by ceili
ASSUM12V     ECO Assumption 12 Value                             20.00
ASSUM13      ECO Assumption 13         square foot coverage per wall s
ASSUM13V     ECO Assumption 13 Value                            120.00
ASSUM14      ECO Assumption 14         percent reduction in on-time by
ASSUM14V     ECO Assumption 14 Value                             30.00
```

Rules file.

```
* This is the occusens.prg program
```

```
* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

numwall = ( xtraare + xrdtare + xhosmedare + xadmare + ;
           xcomfacare ) * 1000 * ( xassum01v / 100 ) / ;
           xassum13v

numceil = ( xtraare + xrdtare +  xhosmedare + xadmare + ;
           xcomfacare ) * 1000 * ( xassum02v / 100 ) / ;
           xassum11v

replace numecouni ;
   with ( numwall + numceil ) * ( 1 - penfac )

* numecouni end

******** Select Project Size Factor********

do comcalc0

********** Calculate Adjusted Initial Cost **********

* inicos start

replace inicos ;
   with ( ( numwall * xcapcost * xassum04v / 100 ) + ;
         ( numceil * xcapcost ) ) * xlocind * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

*********** calculate summer demand saved **********

* sumdemsav start
```

```
replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with -1 * ( ( numwall * xassum09v / 1000 * xassum14v / ;
        100 ) + ( numceil * xassum10v / 1000 * xassum12v / ;
        100 ) ) * xligheafra * xassum03v * 3412 / 1000000 ;
        * xassum05v

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with ( ( numwall * xassum09v / 1000 * xassum14v / ;
        100 ) + ( numceil * xassum10v / 1000 * xassum12v / ;
        100 ) ) * xligcoofra * xassum03v * 3412 / 1000000 * ;
        xaclogtst

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with ( ( numwall * xassum13v / ;
        1000 * xassum14v / 100 ) + ( numceil * xassum10v / ;
        1000 * xassum12v / 100 ) ) * xassum03v * 3412 / ;
        1000000 + cooenesav

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
   replace gasenesav ;
      with 0
```

```
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) ;
         * xgascomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) ;
         * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) ;
         * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) ;
         * xcoacomeff )) ;
         * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) ;
         * xoilcomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) ;
         * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) ;
         * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) ;
         * xcoacomeff )) ;
         * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) ;
```

```
          * xcoacomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff )) ;
          * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

******* Calculate Lbs. of CFCs displaced *******

*cfcdisp start

replace cfcdisp ;
   with 0

*cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with cooenesav * xadjelecos
```

```
* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Miscellaneous

The miscellaneous category in REEP is a catch-all gathering of ECOs that fit into no other clearly defined categories.

Energy Efficient Computers

Background. Computers are in widespread use on DOD installations and produce a significant plug load. Many newer laptops and notebook computers have processors and disk drives that were once available only in desktop computers. These portable computers have very low power consumption and can reduce the plug load. The ECO evaluates the replacement of a 386 class AT and monitor with a 386 class laptop/notebook with a color LCD screen.

Computer characteristics. The new computer has builtin hardware and software energy saving features to turn off the hard drive and screen when not in use. The notebook can regulate the clock speed of the processor to meet the computing load.

Facility assumptions. The ECO assumes computers are found in administration, training, and R&D facilities.

Computer replacement algorithms. The efficient computer algorithm bases energy savings on the difference in energy consumption between old and new units, multiplied by the number of hours the unit would run annually.

Assumptions file.

```
REEP ECO REPORT                                              Page  1
07/13/94

ECO:  Efficient Computers

FIELD     DESCRIPTION                                          VALUE
--------------------------------------------------------------------
ECO       Energy Opportunity                     Efficient Computers
UNIT      Unit                                             Computers
```

ECOTYPE	Energy Opportunity Type	Miscellaneous
PROGRAM	Rules File (Program) Name	efficomp
CAPCOST	Capital Cost	2000.00
RECURCOST	Recurring Cost	0.00
ECONLIFE	Economic Life	10.00
DISCQTY	Discount Quantity	10.00
ASSUM01	ECO Assumption 01	KSF per computer
ASSUM01V	ECO Assumption 01 Value	0.30
ASSUM02	ECO Assumption 02	% of flour area affected
ASSUM02V	ECO Assumption 02 Value	80.00
ASSUM03	ECO Assumption 03	Annual hours of operation
ASSUM03V	ECO Assumption 03 Value	2080.00
ASSUM04	ECO Assumption 04	Wattage of AT & mon.
ASSUM04V	ECO Assumption 04 Value	170.00
ASSUM05	ECO Assumption 05	Wattage of laptop & mon.
ASSUM05V	ECO Assumption 05 Value	82.00

Rules file.

```
* This is the efficomp.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xassum01v = 0
  replace numecouni ;
     with 0
else
  replace numecouni ;
     with ( xtraare + xrdtare + xadmare ) / xassum01v ;
          * ( xassum02v / 100 ) * ( 1 - penfac )
endif

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start
```

```
replace inicos ;

   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

 ********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with ( xassum04v - xassum05v ) * numecouni / 1000

* basdemsav end

******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with basdemsav * 8 * 5 * 52 * 3.412 / 1000
```

```
* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

******* Calculate Lbs. of CFCs displaced *******

* cfcdisp start

replace cfcdisp;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
```

```
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

High Efficiency Refrigerator Replacement

Background. It is not uncommon for refrigerators to last 15 to 20 years. With this in mind, it is not unreasonable to assume that many older refrigerators are still in use in family housing units. Improved refrigeration technologies and cabinet designs have resulted in the new refrigerators being much more energy efficient than their predecessors. Observed individually, refrigerators are not often viewed as being great energy consumers, however, since every family housing unit has one, and since they run 24 hours a day year-round, their aggregate consumption is significant. Refrigerators use approximately 20 percent of all household electricity (Energy Information Administration 1987).

Refrigerator characteristics. In a study jointly funded by the Empire State Electric Energy Research Corp., the New York Energy Research Corp., and the Electric Power Research Institute, Rochester Gas & Electric replaced old refrigerators in 27 homes with new efficient ones. The new units were typically larger and had more features than the ones they replaced. Nevertheless, average energy use declined 60 percent or 1,300 KWh per year (Meier, January/February 1993).

kWh savings per refrigerator:	1,300
Installed cost per unit ($):	600
Economic Life (yr):	20
Recurring Costs (% of initial cost):	0

Facility assumptions. This ECO models the replacement of one-half of all of the refrigerators found in family housing units. It is assumed that the remaining units are new or relatively new and don't currently warrant replacement. To err on the conservative side of energy savings, no credit has been taken for demand savings, although in actuality, there would be some. Furthermore, no increase and decrease in heating and cooling loads respectively have been considered since the overall effect of the higher efficiency refrigerators would be negligible.

Refrigerator conclusions. Replacing older refrigerators with new units pays back in less than ten years at several installations. Naturally, it is at those installations with high electrical costs where the units qualify. The best part of ECOs such as refrigerator replacement is that refrigerators require very little to no maintenance. You plug them in and walk away from them. ECOs such as this impose no additional burden on the maintenance staff and save energy from the day they are installed.

Assumptions file.

```
REEP ECO REPORT                                              Page 1
09/01/94

ECO:  High Eff Refrig Replcmnt

FIELD       DESCRIPTION                                       VALUE
--------------------------------------------------------------------
ECO         Energy Opportunity              High Eff Refrig Replcmnt
UNIT        Unit                                            Refrgrtrs
ECOTYPE     Energy Opportunity Type                     Miscellaneous
PROGRAM     Rules File (Program) Name                       highrefr
CAPCOST     Capital Cost                                      600.00
RECURCOST   Recurring Cost                                      0.00
ECONLIFE    Economic Life                                      20.00
DISCQTY     Discount Quantity                                  10.00
ASSUM01     ECO Assumption 01                      KSF per refrigerator
ASSUM01V    ECO Assumption 01 Value                             1.50
ASSUM02     ECO Assumption 02                          % of FH retrofit
ASSUM02V    ECO Assumption 02 Value                            50.00
ASSUM03     ECO Assumption 03               KWh savings per refrigerator
ASSUM03V    ECO Assumption 03 Value                          1300.00
```

Rules file.

```
* This is the highrefr.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xassum01v = 0
  replace numecouni ;
     with 0
else
  replace numecouni ;
      with xfamhouare / xassum01v * xassum02v / 100 ;
           * ( 1 - penfac )
endif

* numecouni end

********* Select Project Size Factor **************

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start
```

```
replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with numecouni * xassum03v * 3.412 / 1000

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********
```

```
* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

*  SECTION 3 - ECO specific calculations that override common
calculations
```

Renewables

The Renewables category addresses technologies that use solar and wind energy as an energy source. Water and air can be heated with solar energy rather than using fossil fuels. Electricity can be generated with photovoltaics and wind turbines instead of fossil fuel, nuclear power, or hydropower. Currently most of the renewable technologies have relatively long paybacks since they are expensive to implement and compete against cheap energy sources.

The renewable ECOs have both advantages and disadvantages. Advantages include a reduced dependency on outside sources of energy, capitalizing on renewable energy, and reduced pollution generation. Disadvantages include high initial costs, long payback periods, and possibly increased maintenance. The societal benefits due to reduction in pollution generation are not included in the economic evaluation for renewable ECOs.

All the renewable ECOs depend strictly on climatic variables. The solar ECOs obviously require solar radiation to be effective and the wind turbines require substantial air movement to function economically. Therefore, certain climatic conditions may rule out the viability of some of the renewable ECOs.

Several opportunities for renewables, particularly photovoltaics, were not included in the REEP model due to the difficulty of having some type of metric at each installation that could be used to identify the number of opportunities. The REEP list of renewable ECOs is by no means comprehensive.

Solar Water Heating for Barracks

Background. In climates with moderate to high levels of solar radiation, solar energy can offset the use of fossil fuels to heat domestic hot water. Some utilities even provide rebates to install solar hot water heating systems in an effort to reduce peak electrical demand.

Solar water heating for barracks characteristics.

Cost per installation ($):	72,598	per barracks unit
Recurring cost (%):	1	This is the uniform annual cost for maintenance as a percent of the capital cost
Economic Life (yr):	20	
Energy Factor:	11.00	dimensionless
Collector Area (sq ft):	1,750	

Facility assumptions. This ECO only applies to barracks type facilities.

Typical barracks unit size (KSF):	45.6	
Typical consumption per day (gal):	4000	Assume 20 gal/day/person x 200 persons per barracks
Inlet water temperature (°F):	58	
Outlet water temperature (°F):	140	

Solar water heating for barracks conclusions. Due to the high cost of solar water heating, this ECO does not meet ECIP criteria at any installation. However, the cost of solar units is dropping and this technology will become more cost effective with time.

Assumptions file.

```
REEP ECO REPORT                                              Page 1
09/01/94

ECO:  Barracks Solar Water Htg

FIELD       DESCRIPTION                                       VALUE
-------------------------------------------------------------------
ECO         Energy Opportunity               Barracks Solar Water Htg
UNIT        Unit                                             Barracks
ECOTYPE     Energy Opportunity Type                        Renewables
PROGRAM     Rules File (Program) Name                        solawhba
CAPCOST     Capital Cost                                     72598.00
RECURCOST   Recurring Cost                                       1.00
ECONLIFE    Economic Life                                       20.00
DISCQTY     Discount Quantity                                   10.00
ASSUM01     ECO Assumption 01           Typical consumption per day (ga
ASSUM01V    ECO Assumption 01 Value                           4000.00
ASSUM02     ECO Assumption 02                   Typical unit size (ksf)
ASSUM02V    ECO Assumption 02 Value                             45.60
ASSUM03     ECO Assumption 03               Outlet water temperature (F)
ASSUM03V    ECO Assumption 03 Value                            140.00
ASSUM04     ECO Assumption 04                           Energy Factor
ASSUM04V    ECO Assumption 04 Value                             11.00
ASSUM05     ECO Assumption 05                       Collector Area (SF)
ASSUM05V    ECO Assumption 05 Value                           1750.00
```

Rule file.

```
* This is the solawhba.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********
```

```
do comcalc

********** calculate number of ECO units **********

* numecouni start

if xassum02v <> 0
  if xbarare > 200
    replace numecouni ;
       with ( 1 - penfac ) * xbarare / xassum02v
  else
    replace numecouni ;
       with 0
  endif
else
  replace numecouni ;
     with 0
endif

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * 365 / 1000000 * xassum01v * ( xassum03v ;
        - xgrotem ) * 8.33 * ( 1 - ( 1500 / ( xassum04v * ;
        xtotglorad ) ) )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start
```

```
replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with 0

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
  with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

x = xghp35con + xohp35con + xchp35con + xghp7535con + xohp7535con +
xchp7535con
if x = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con ) * xgascomeff / ;
        ((( xghp35con + xghp7535con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con ) * xcoacomeff )) ;
         * heaenesav / ( xgascomeff / 100 )
endif
```

```
* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

x = xghp35con + xohp35con + xchp35con + xghp7535con + xohp7535con +
xchp7535con
if x = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con ) * xoilcomeff / ;
        ((( xghp35con + xghp7535con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con ) * xcoacomeff )) ;
         * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

x = xghp35con + xohp35con + xchp35con + xghp7535con + xohp7535con +
xchp7535con
if x = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con ) * xcoacomeff / ;
        ((( xghp35con + xghp7535con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con ) * xcoacomeff )) ;
         * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water volume saved **********

* watvolsav start

replace watvolsav ;
   with 0
```

```
* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Attached Sunspaces for Family Housing

Background. Attached sunspaces can reduce heating energy consumption by using heat from the sun to warm the indoors during the winter. Besides energy conservation benefits, sunspaces also provide an attractive living space, an area for children to play, and the opportunity to grow plants indoors.

Sunspace characteristics. Sunspaces are attached to the exterior of the south-facing wall of suitable family housing units. Existing windows and doors are kept in place to

provide a path for the warm sunspace air to enter the house. It is assumed that the windows and doors can be shut at night in the winter to prevent heat losses and in the summer to prevent heat gain. The sunspace considered is approximately 9 ft tall, 8 ft wide, and 24 ft long with double pane windows. It is assumed that the sunspace faces directly south, uses the wall of the house for heat storage, and the collector glazing is tilted 50 degrees to the horizontal.

Collector Area (sq ft):	210	
Total Installed Cost ($):	7,000	(Chandler 1992)
Recurring cost (% of CC):	0	
Economic life (years):	20	
Balance temperature [°F]:	60	

Facility assumptions. It is assumed that this ECO applies to 25 percent of available family housing units.

% of total facility space applicable:	25
Average housing unit area (sq ft):	1,500

Sunspace algorithms.

Heating Savings (Mbtu/yr) = [6,875 x HDD] - [7,732 x HDD x (1.0 - (0.0168 x VT2/DD) / 1,000,000] x ECO_{units}
(Military Handbook [MIL-HDBK] 1003/19, 3 May 1987)

Cooling Savings (MBtu/yr) = 0

Electric Savings (MBtu/yr) = 0

Demand Savings (kW) = 0

where:

HDD = Heating Degree Days

VT2/DD = South/Vertical Transmitted Radiation to Degree Day Ratio

ECO_{units} = The sunspaces installed per installation.

Sunspace conclusions. Because of their high capital cost, sunspaces rarely achieve an acceptable payback. In areas with low winter temperatures and high incident solar

radiation, sunspaces may be acceptable when the asthetic value is considered in the final decision.

Assumptions file.

```
REEP ECO REPORT                                                  Page 1
09/01/94

ECO:  FH Passive Solar Sunspace

FIELD        DESCRIPTION                                          VALUE
-------------------------------------------------------------------------
ECO          Energy Opportunity              FH Passive Solar Sunspace
UNIT         Unit                                                 Rooms
ECOTYPE      Energy Opportunity Type                         Renewables
PROGRAM      Rules File (Program) Name                         pasolrfh
CAPCOST      Capital Cost                                       7000.00
RECURCOST    Recurring Cost                                        0.00
ECONLIFE     Economic Life                                        20.00
DISCQTY      Discount Quantity                                    10.00
ASSUM01      ECO Assumption 01             Percent of housing applicable
ASSUM01V     ECO Assumption 01 Value                              25.00
ASSUM02      ECO Assumption 02            Average area [ft2] of family ho
ASSUM02V     ECO Assumption 02 Value                            1500.00
```

Rules file.

```
* This is the pasolrfh.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

      replace numecouni ;
       with xfamhouare * 1000 * ( xassum01v / 100 ) / ;
             xassum02v  * ( 1 - penfac )

* numecouni end

**********Select Project Size Factor*************

do comcalc0
```

```
**********Calculate adjusted initial cost********

* inicos start

replace inicos ;
 with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with ( ( ( 6875 * xhdd ) - ( 7732 * xhdd * ( 1.0 - ;
        ( 0.0168 * xvtdd ) ) ) ) / 1000000) * numecouni

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
    with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with 0

* eleenesav end

*********Calculate summer demand saved*************

* sumdemsav start

replace sumdemsav ;
 with 0

* sumdemsav end

*********Calculate baseload demand saved***********

* basdemsav start
```

```
replace basdemsav ;
 with 0

* basdemsav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ;
          / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ) ;
          + ( ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ) ;
          + ( ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ) ) ;
          * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ;
          / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ) ;
          + ( ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ) ;
          + ( ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ) ) ;
          * heaenesav / ( xoilcomeff / 100 )
endif
```

```
* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ;
          / ( ( ( xghp35con + xghp7535con + xghp75con ) ;
          * xgascomeff ) ;
          + ( ( xohp35con + xohp7535con + xohp75con ) ;
          * xoilcomeff ) ;
          + ( ( xchp35con + xchp7535con + xchp75con ) ;
          * xcoacomeff ) ) ;
          * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water volume saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

* cfcdisp start

replace cfcdisp ;
 with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
```

```
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Solar Water Heating for Family Housing

Background. In climates with moderate to high levels of solar radiation, solar energy can offset the use of fossil fuels to heat domestic hot water. Some utilities even provide rebates to install solar hot water heating systems in an effort to reduce peak electrical demand.

Solar water heating for family housing characteristics.

Cost per installation ($):	2,431	per housing unit	
Recurring cost (%):	1	This is the uniform annual cost for maintenance as a percent of the capital cost.	
Economic Life (yr):	20		
Energy Factor:	6.50	Dimensionless	(Block 1992)
Collector Area (sq ft):	42		

Facility assumptions. This ECO applies only to family housing units.

Typical FH unit size (KSF):	1.5
Typical consumption per day (gal):	64.3
Inlet water temperature (°F):	58
Outlet water temperature (°F):	135

Solar water heating for family housing conclusions. Due to the high cost of solar water heating for family housing, this ECO only meets ECIP criteria at four installations.

However, the cost of solar units is dropping, and this technology will become more cost effective with time.

Assumptions file.

```
REEP ECO REPORT                                                Page 1
09/01/94

ECO:  FH Solar Water Htg

FIELD      DESCRIPTION                                          VALUE
-------------------------------------------------------------------------
ECO        Energy Opportunity                      FH Solar Water Htg
UNIT       Unit                                                Houses
ECOTYPE    Energy Opportunity Type                         Renewables
PROGRAM    Rules File (Program) Name                         solawhfh
CAPCOST    Capital Cost                                       2431.00
RECURCOST  Recurring Cost                                        1.00
ECONLIFE   Economic Life                                        20.00
DISCQTY    Discount Quantity                                    10.00
ASSUM01    ECO Assumption 01             Typical consumption per day (ga
ASSUM01V   ECO Assumption 01 Value                              82.00
ASSUM02    ECO Assumption 02                    Typical unit size (ksf)
ASSUM02V   ECO Assumption 02 Value                               1.50
ASSUM03    ECO Assumption 03                                Energy Factor
ASSUM03V   ECO Assumption 03 Value                               6.50
ASSUM04    ECO Assumption 04                Outlet water temperature (F)
ASSUM04V   ECO Assumption 04 Value                             135.00
```

Rules file.

```
* This is the solawhfh.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with ( 1 - penfac ) * xfamhouare / xassum02v

* numecouni end

********** Select Project Size Factor ******
```

```
do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
  with 0

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * 365 / 1000000 * xassum01v * ( xassum04v ;
        - xgrotem ) * 8.33 * ( 1 - ( 1500 / ( xassum03v ;
        * xtotglorad ) ) )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end
```

```
********** calculate electric fuel saved **********

* eleenesav start

if ( xghp75cap + xghp75con ) = 0
  replace eleenesav ;
     with heaenesav / 0.97
else
  if xghp75con + xohp75con + xchp75con > 0
    replace eleenesav ;
       with heaenesav / 0.97 * ( 1 - ( xghp75con / ;
             ( xghp75con + xohp75con + xchp75con ) ) )
  else
    replace eleenesav ;
       with 0
  endif
endif

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

if xghp75cap + xghp75con > 0 .and. xghp75con ;
   + xohp75con + xchp75con > 0
   replace gasenesav ;
      with ( xghp75con ) * xgascomeff / ;
        ((( xghp75con ) * xgascomeff ) + ;
         (( xohp75con ) * xoilcomeff ) + ;
         (( xchp75con ) * xcoacomeff )) ;
        * heaenesav / ( xgascomeff / 100 )
else
   replace gasenesav ;
      with 0
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********
```

```
* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water volume saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2
```

```
* SECTION 3 - ECO specific calculations that override common
calculations
```

Microclimate Modifications

Background. Microclimate modifications can range from the type of surfacing material used on parking lots, to the color of buildings, to the type, amount, and location of vegetation. This ECO analyzes the amelioration of the microclimate immediately surrounding family housing units using strategically located trees. Extensive research has shown that the proper type, amount, and location of vegetation can have dramatic effects on the energy consumption characteristics of buildings. During summer months, proper shading of eastern, southern, and particularly western elevations can significantly reduce solar loads on buildings, thus reducing the need for air-conditioning. During winter months, vegetation used to divert wind can greatly reduce infiltration and thus heating requirements.

Microclimate modifications characteristics. This ECO is only applied to family housing units, however, it could be applicable also to a fair amount of small administrative, training, and medical type facilities. This ECO models the effects of two trees on the western elevation and one on the southern elevation. At installations that do not qualify for air-conditioning, only heating savings benefits are calculated. An allowance of $100 per tree was used. If actually implemented, each installation would need to analyze specific climatic, soil, and functional issues and tree selection on localized criteria.

Cooling, peak, and heating reductions are all calculated individually for each installation. Also calculated are the quantity and cost increases attributable to increased water consumption. Recurring costs have been set at $10/yr/tree to account for removal and replacement of dead trees and maintenance. Not included are the non-quantifiable environmental and aesthetic benefits that would also result from a microclimate modification program.

Peak reduction, and heating and cooling savings are based on a study performed at Lawrence Berkeley Laboratory (LBL) (Huang, Akbari, and Taha, January 1990). This study used DOE 2.1d to model the effects of various densities of tree vegetation on older and newer type residences in seven different climatic regions. This ECO used the results of the 30 percent tree canopy (i.e., three trees per house) model on pre-1973 residences. The reductions and, in some instances, increases in energy consumption are due to reduction in solar loads and reduced infiltration. Table D10 presents the results from this portion of the LBL study. Columns 1 through 5 and 9 are directly from the LBL study. Column 6 converts column 5 to MBtu and columns 7 and 8 adjust the LBL

results to a 1,500 sq ft residence. The LBL study used different sized residences based on findings of a Residential Energy Consumption Survey conducted in 1980-81.

Regressions were performed on the Table D10 data to relate HDDs and CDDs to reductions in heating, cooling, and peak reductions. The regression coefficients were used along with each installation's HDD and CDD to determine heating, cooling, and peak reductions. The calculated savings take into account mechanical system efficiencies.

Technical potential and saturation are also considered to determine the number of opportunities for tree planting (McPherson 1993). Technical potential describes the percentage of buildings that are situated so they could benefit from tree planting. Saturation describes how much of the technical potential is already satisfied. Therefore, the technical potential minus the saturation equals the remaining potential. Remaining potentials would naturally vary from one installation to another and are thus specified as variables in the program.

Water consumption is considered for this ECO but is a highly mutable variable. Water consumption varies with tree species, size, time of year, and climate. A quantity of water consumption per day is specified for all three trees. This value is then multiplied by 365 days/yr and divided by 1000 to obtain kilogallons/yr of water consumed. The water consumption is multiplied by the unit cost of water at each installation, and this value is considered an annual cost (along with maintenance) in the economic analysis.

Facility assumptions. The only facility assumption required for this ECO was the square footage of a family housing unit. All other assumptions relating to facility characteristics were made in the LBL study and were considered appropriate for military housing.

Square feet per Family Housing unit (KSF): 1.5

Table D10. Changes in energy consumption due to reduced solar loads and reduced infiltration.

1 Location	2 HDD	3 CDD	4 Htg. MBtu	5 Clg. kWh	6 Clg. MBtu	7 Adj. H. MBtu	8 Adj. C. MBtu	9 Clg. kW	10 Adj. C. kW
Chicago	6,120	969	15.6	492	1.68	16.71	1.80	0.80	0.86
Miami	222	3,922	-0.1	1,951	6.66	-0.11	7.13	0.50	0.54
Minneapolis	8,004	727	11.3	359	1.22	12.11	1.31	0.70	0.75
Phoenix	1,320	3,609	1.5	1,682	5.74	1.61	6.15	0.50	0.54
Pittsburgh	5,923	590	8.2	417	1.42	7.69	1.33	0.65	0.61
Sacramento	2,713	1,128	2.4	681	2.32	2.57	2.49	1.03	1.10
Washington	4,180	1,388	13.9	753	2.57	10.43	1.93	1.27	0.95

Microclimate modifications conclusions. Some important points regarding this ECO should be highlighted. Economic feasibility of this ECO depends on the recurring costs. This dependence reinforces the necessity to critically examine each installation individually to develop a landscaping program that minimizes functional requirements such as maintenance and upkeep.

Recent advances in tree hybridization have developed certain "super-trees" that grow at phenomenal rates. Planting trees is often regarded as a slow-to-mature energy conservation option, but this preconception may have to be revised. Some of the hybrids can grow 15 ft a year during initial stages of development. Rather than being 5 to 10 years before any savings accrue from tree planting, it may only be a couple of years.

This ECO, more than any other one analyzed in REEP, has the potential to not only save energy, but to vastly improve the character of family housing developments in the Army. Unfortunately, many benefits attributable to this ECO are unquantifiable and thus cannot be included in this analysis.

Assumptions file.

```
REEP ECO REPORT                                              Page  1
07/13/94

ECO:  Microclimate Modifications
```

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	Microclimate Modifications
UNIT	Unit	Houses
ECOTYPE	Energy Opportunity Type	Renewables
PROGRAM	Rules File (Program) Name	micrclim
CAPCOST	Capital Cost	377.00
RECURCOST	Recurring Cost	30.00
ECONLIFE	Economic Life	20.00
DISCQTY	Discount Quantity	20.00
ASSUM01	ECO Assumption 01	KSF per FH unit
ASSUM01V	ECO Assumption 01 Value	1.50
ASSUM02	ECO Assumption 02	Technical Potential
ASSUM02V	ECO Assumption 02 Value	50.00
ASSUM03	ECO Assumption 03	Water consumption per day (gal)
ASSUM03V	ECO Assumption 03 Value	30.00
ASSUM04	ECO Assumption 04	Original Demand Diversity
ASSUM04V	ECO Assumption 04 Value	0.98
ASSUM05	ECO Assumption 05	Retrofit Demand Diversity
ASSUM05V	ECO Assumption 05 Value	0.96

Rules file.

```
* This is the micrcli2.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xassum01v = 0
  replace numecouni ;
     with 0
else
  replace numecouni ;
     with xfamhouare / xassum01v * xassum02v / 100 ;
     * ( 1 - penfac )
endif

* numecouni end

********* Select Project Size Factor **************

do comcalc0

********** calculate adjusted initial cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * ( xhdd * 0.001898 - 0.436554 )

* heaenesav end

********** calculate cooling energy saved **********
```

```
* cooenesav start

if xaclogtst = 1
  replace cooenesav ;
     with numecouni * ( xcdd * 0.001721 + 0.131641 )
else
  replace cooenesav ;
     with 0
endif

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

if cooenesav = 0
  replace sumdemsav ;
     with 0
else
  replace sumdemsav ;
     with numecouni * ( xcdd * -0.000092 + 0.925969 )
          * ( xassum04v - xassum05v )
endif

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start
```

```
zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) * xgascomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) * xoilcomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) * xcoacomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xcoacomeff / 100 )
```

```
endif

* coaenesav end

********** calculate water volume saved **********

* watvolsav start

replace watvolsav ;
   with numecouni * ( - xassum03v ) * 365 / 1000

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with watvolsav * xwatseru

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

*  SECTION  3  -  ECO  specific  calculations  that  override  common
calculations
```

Photovoltaic Peaking Station

Background. Photovoltaic (PV) cells convert sunlight into electricity. When these cells are connected in a large array, they can provide electricity to the installation's grid through an inverter. The array's output profile matches well with most installation's demand for electricity during the day.

Photovoltaic peaking station characteristics. This ECO analyzes one PV peaking station on each installation. The PV peaking station is grid connected. During the summer, when most installations reach their peak, the solar radiation is often at its highest, boosting the PV panels to maximum output.

Facility assumptions. None: The PV peaking station is sized based on the entire installation's demand.

Photovoltaic peaking station algorithms. The PV peaking station bases energy savings on the total global radiation available at each installation. The dollar savings is based on the cost of offset kW and kWh.

Assumptions file.

```
REEP ECO REPORT                                              Page  1
07/14/94

ECO:  Photovoltaic Peaking Station
```

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	Photovoltaic Peaking Station
UNIT	Unit	Kw
ECOTYPE	Energy Opportunity Type	Renewables
PROGRAM	Rules File (Program) Name	photovol
CAPCOST	Capital Cost	6500.00
RECURCOST	Recurring Cost	2.00
ECONLIFE	Economic Life	20.00
DISCQTY	Discount Quantity	5.00
ASSUM01	ECO Assumption 01	PV station size= % peak demand
ASSUM01V	ECO Assumption 01 Value	0.01
ASSUM02	ECO Assumption 02	Annual hours of operation
ASSUM02V	ECO Assumption 02 Value	2100.00
ASSUM03	ECO Assumption 03	Power output diversity factor
ASSUM03V	ECO Assumption 03 Value	0.60
ASSUM04	ECO Assumption 04	Full output achieved at (Btu/SF
ASSUM04V	ECO Assumption 04 Value	1850.00

Rules file.

```
* This is the photovol.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xassum01v = 0
  replace numecouni ;
     with 0
else
  replace numecouni ;
     with xelekwpdem * xassum01v * ( 1 - penfac )
endif

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********
```

```
* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with numecouni * xtotglorad / xassum04v

* basdemsav end

******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with basdemsav * xassum02v * xassum03v * 3.412 / 1000

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0
```

```
* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

**** Calculate Lbs. of CFCs displaced *****

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0
```

```
* henecossav end

do comcalc2

*  SECTION 3 - ECO specific calculations that override common
calculations
```

Solar Street Lighting

Background. An alternative to standard street lights are street lights that incorporate PV panels, batteries, and control circuitry. These lights are completely standalone and do not need any utility connection. This ECO models the replacement of existing mercury vapor street lights with the PV version. The batteries for these units have sufficient capacity to power the lights for 5 consecutive days without sun.

Solar street lighting characteristics. The following assumptions were made regarding the existing and retrofit street lamps.

Existing Mercury Vapor Lamp Wattage (W):	400
Installed Cost ($):	2,000
Economic Life (years):	15
Recurring Costs (% of initial cost):	0

Solar street lighting assumptions. This ECO applies only to street lighting. It models the replacement of existing street lights with solar powered street lights. It is assumed that not all locations of existing street lights would be ideally suited for solar street lights, thus this ECO is applied only to a certain percentage of the existing stock of lights.

Percent of applicable fixtures (%):	75	
Annual hours of operation (hr):	2500	(12 hr/day x 365 days/yr)

Solar street lighting retrofit conclusions. This ECO does not qualify for ECIP funding at most installations due to its high capital cost. These types of lights are considered a new technology and so costs are still quite high; however, cost of these units should drop with time. Solar street lights are ideally suited for new construction and their payback would be much better than indicated by this analysis. No utilities would need to be run to each light, so no infrastructure would be required.

Assumptions file.

REEP ECO REPORT Page 1
09/01/94

ECO: Solar Street Lighting

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	Solar Street Lighting
UNIT	Unit	Fixtures
ECOTYPE	Energy Opportunity Type	Renewables
PROGRAM	Rules File (Program) Name	solastre
CAPCOST	Capital Cost	2000.00
RECURCOST	Recurring Cost	0.00
ECONLIFE	Economic Life	15.00
DISCQTY	Discount Quantity	40.00
ASSUM01	ECO Assumption 01	Street light application (%)
ASSUM01V	ECO Assumption 01 Value	75.00
ASSUM02	ECO Assumption 02	Annual hours of operation
ASSUM02V	ECO Assumption 02 Value	4380.00
ASSUM03	ECO Assumption 03	Existing fixture wattage
ASSUM03V	ECO Assumption 03 Value	250.00
ASSUM04	ECO Assumption 04	
ASSUM04V	ECO Assumption 04 Value	0.00
ASSUM05	ECO Assumption 05	
ASSUM05V	ECO Assumption 05 Value	0.00
ASSUM06	ECO Assumption 06	
ASSUM06V	ECO Assumption 06 Value	0.00
ASSUM07	ECO Assumption 07	
ASSUM07V	ECO Assumption 07 Value	0.00
ASSUM08	ECO Assumption 08	
ASSUM08V	ECO Assumption 08 Value	0.00
ASSUM09	ECO Assumption 09	
ASSUM09V	ECO Assumption 09 Value	0.00
ASSUM10	ECO Assumption 10	
ASSUM10V	ECO Assumption 10 Value	0.00
ASSUM11	ECO Assumption 11	
ASSUM11V	ECO Assumption 11 Value	0.00
ASSUM12	ECO Assumption 12	
ASSUM12V	ECO Assumption 12 Value	0.00
ASSUM13	ECO Assumption 13	
ASSUM13V	ECO Assumption 13 Value	0.00
ASSUM14	ECO Assumption 14	
ASSUM14V	ECO Assumption 14 Value	0.00
ASSUM15	ECO Assumption 15	
ASSUM15V	ECO Assumption 15 Value	0.00
ASSUM16	ECO Assumption 16	
ASSUM16V	ECO Assumption 16 Value	0.00
ASSUM17	ECO Assumption 17	
ASSUM17V	ECO Assumption 17 Value	0.00

ASSUM18	ECO Assumption 18	
ASSUM18V	ECO Assumption 18 Value	0.00
ASSUM19	ECO Assumption 19	
ASSUM19V	ECO Assumption 19 Value	0.00
ASSUM20	ECO Assumption 20	
ASSUM20V	ECO Assumption 20 Value	0.00

Rules file.

```
* This is the solastre.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with xextlig * xassum01v / 100 * ( 1 - penfac )

* numecouni end

********* Select Project Size Factor **************

do comcalc0

********** calculate adjusted initial cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********
```

```
* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with numecouni * xassum03v * xassum02v * 3.412 / 1000000

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0
```

```
* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0
```

```
* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

SolarWall for Maintenance Buildings

Background. Army maintenance buildings have a high demand for makeup air. Exhaust fumes, solvents, and other tasks create the need for large amounts of fresh air to maintain acceptable indoor air quality. Providing large volumes of heated air during the winter months can be expensive. Rather than use fossil fuels to heat the fresh air, renewable solar energy can be used instead. SolarWall is an air-makeup system patented by Conserval/SolarWall and designed to produce heated ventilation air and distribute it throughout a building. Solar panels on a south facing wall preheat the fresh air supply to the building.

SolarWall characteristics. SolarWall can be incoporated as an integral part of the south wall of a new building, or it can be retrofit onto a southern elevation of an existing structure.

Collector Efficiency (%):	75
Destratification credit (%):	58
Exhaust credit (%):	74
Installed Cost ($/SF):	18
Economic Life (years):	20
Recurring Costs (% of initial cost):	0

(Source: Hollick and Aslin 1990).

Facility assumptions. This ECO applies only to maintenance type facilities in climates with more than 3,000 HDDs. This ECO assumes that only 33 percent of all maintenance buildings are potential candidates for SolarWall. The other 67 percent will not be optimally oriented or have other conditions that preclude the use of the SolarWall system. Square footage of the SolarWall is calculated as being 8 percent of the remaining square footage.

SolarWall algorithms. Savings from this ECO are calculated so the load collected by the SolarWall displaces heating that is otherwise provided by the conventional makeup air system. The SolarWall is modeled as facing due south, and the angle between the solar radiation and the SolarWall is calculated for 10 a.m.

SolarWall conclusion. SolarWall results indicate that this ECO is a viable option at 16 installations. One very appealing aspect of this ECO is its simplicity. There is very little to maintain in a SolarWall system. The other attractive aspect of the SolarWall system is its use of renewable energy rather than depending on fossil fuels to heat makeup air.

Assumptions file.

```
REEP ECO REPORT                                                   Page 1
09/01/94

ECO:  SolarWall for Maint Bldgs
FIELD       DESCRIPTION                                            VALUE
-------------------------------------------------------------------------
ECO         Energy Opportunity                 SolarWall for Maint Bldgs
UNIT        Unit                                                 Sq. Ft.
ECOTYPE     Energy Opportunity Type                           Renewables
PROGRAM     Rules File (Program) Name                           solawall
CAPCOST     Capital Cost                                           18.00
RECURCOST   Recurring Cost                                          0.00
ECONLIFE    Economic Life                                          20.00
DISCQTY     Discount Quantity                                    5000.00
ASSUM01     ECO Assumption 01              Percentage of applicable bldgs
ASSUM01V    ECO Assumption 01 Value                                33.00
ASSUM02     ECO Assumption 02                 Heating degree days cutoff
ASSUM02V    ECO Assumption 02 Value                              3000.00
ASSUM03     ECO Assumption 03                           Plant efficiency
ASSUM03V    ECO Assumption 03 Value                                65.00
ASSUM04     ECO Assumption 04                  Solar wall to floor ratio
ASSUM04V    ECO Assumption 04 Value                                 0.06
ASSUM05     ECO Assumption 05                       Collector efficiency
ASSUM05V    ECO Assumption 05 Value                                75.00
ASSUM06     ECO Assumption 06               Destratification credit (%)
ASSUM06V    ECO Assumption 06 Value                                58.00
ASSUM07     ECO Assumption 07                 Exhaust savings credit (%)
ASSUM07V    ECO Assumption 07 Value                                74.00
ASSUM08     ECO Assumption 08                                         Rt
ASSUM08V    ECO Assumption 08 Value                                 1.30
ASSUM09     ECO Assumption 09                       Gas Plant Efficiency
ASSUM09V    ECO Assumption 09 Value                                70.00
ASSUM10     ECO Assumption 10                       Oil Plant Efficiency
ASSUM10V    ECO Assumption 10 Value                                65.00
ASSUM11     ECO Assumption 11                      Coal Plant Efficiency
ASSUM11V    ECO Assumption 11 Value                                60.00
```

Rules file.

```
* This is the solawall.prg program
```

```
* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xhdd > xassum02v
  replace numecouni ;
      with xmaiproare * xassum01v / 100 * 1000 * xassum04v ;
           * ( 1 - penfac )
else
  replace numecouni ;
     with 0
endif

* numecouni end

********* Select Project Size Factor **************

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with xlocind * numecouni * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with ( numecouni * xtotglorad * xassum08v * 150 * ;
        ( ( -sin ( ( 0.0174532 ) * ( -15 ) ) * ;
        cos ( ( 0.0174532 ) * ( xlatdeg ) ) ) + ;
        cos ( ( 0.0174532 ) * ( -15 ) ) * ;
        sin ( ( 0.0174532 ) * ( xlatdeg ) ) * ;
        cos ( ( 0.0174532 ) * ( 30 ) ) ) ) * xassum05v ;
        / 100 ) * ( 1 + xassum06v / 100 + xassum07v ;
        / 100 ) / ( xassum03v / 100) /  1000000

* heaenesav end
```

```
********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with 0

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

x = xghp35con + xohp35con + xchp35con + xghp7535con + xohp7535con +
xchp7535con
if x = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( heaenesav / ( xgascomeff / 100 ) ) * ( xghp35con ;
          + xghp7535con ) / ( xghp35con + xohp35con + ;
```

```
          xchp35con + xghp7535con + xohp7535con + ;
          xchp7535con )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

x = xghp35con + xohp35con + xchp35con + xghp7535con + xohp7535con +
xchp7535con
if x = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( heaenesav / ( xoilcomeff / 100 ) ) * ( xohp35con ;
          + xohp7535con ) / ( xghp35con + xohp35con + ;
          xchp35con + xghp7535con + xohp7535con + ;
          xchp7535con )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

x = xghp35con + xohp35con + xchp35con + xghp7535con + xohp7535con +
xchp7535con
if x = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( heaenesav / ( xcoacomeff / 100 ) ) * ( xchp35con ;
          + xchp7535con ) / ( xghp35con + xohp35con + ;
          xchp35con + xghp7535con + xohp7535con + ;
          xchp7535con )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
```

```
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Wind Energy

Background. Wind can be used as a source of power for pumping or generating electricity, and several windmills can be tied together to provide electricity for Army installations.

Wind energy characteristics. This ECO analyzes windmills on each installation. Windmills were analyzed on installations in areas that have a wind power class rating of three or above.

Facility assumptions. None: The number of windmills is based on the entire installation's demand (5 percent of peak). The power output of the turbine depends on the wind class at the installation.

Wind algorithms. Wind energy was analyzed on installations in areas that have a power class rating of three or above. Five percent of the installation's peak demand was used the size the wind farm. The height and size of the turbines was fixed. The swept area of the turbine multiplied by the wind power class results in the output of a single turbine. This was divided into the 5 percent of peak demand to determine the number of turbines needed. Table D11 lists wind power generated by turbines in various wind classes.

Table D11. Wind power generated by turbines 10 m above ground.

Wind Class	Wind Power W/m^2
3	150
4	200
5	250
6	300
7	400

Assumptions.

```
REEP ECO REPORT                                                Page  1
07/13/94

ECO:  Microclimate Modifications
FIELD      DESCRIPTION                                           VALUE
-----------------------------------------------------------------------
ECO         Energy Opportunity            Microclimate Modifications
UNIT        Unit                                              Houses
ECOTYPE     Energy Opportunity Type                       Renewables
PROGRAM     Rules File (Program) Name                       micrclim
CAPCOST     Capital Cost                                      377.00
RECURCOST   Recurring Cost                                     30.00
ECONLIFE    Economic Life                                      20.00
DISCQTY     Discount Quantity                                  20.00
ASSUM01     ECO Assumption 01                        KSF per FH unit
ASSUM01V    ECO Assumption 01 Value                             1.50
ASSUM02     ECO Assumption 02                    Technical Potential
```

ASSUM02V	ECO Assumption 02 Value	50.00
ASSUM03	ECO Assumption 03	Water consumption per day (gal)
ASSUM03V	ECO Assumption 03 Value	30.00
ASSUM04	ECO Assumption 04	Original Demand Diversity
ASSUM04V	ECO Assumption 04 Value	0.98
ASSUM05	ECO Assumption 05	Retrofit Demand Diversity
ASSUM05V	ECO Assumption 05 Value	0.96

Rules file.

```
* This is the micrcli2.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xassum01v = 0
  replace numecouni ;
     with 0
else
  replace numecouni ;
     with xfamhouare / xassum01v * xassum02v / 100 ;
     * ( 1 - penfac )
endif

* numecouni end

********* Select Project Size Factor **************

do comcalc0

********** calculate adjusted initial cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start
```

```
replace heaenesav ;
   with numecouni * ( xhdd * 0.001898 - 0.436554 )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

if xaclogtst = 1
  replace cooenesav ;
     with numecouni * ( xcdd * 0.001721 + 0.131641 )
else
  replace cooenesav ;
     with 0
endif

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

if cooenesav = 0
  replace sumdemsav ;
     with 0
else
  replace sumdemsav ;
     with numecouni * ( xcdd * -0.000092 + 0.925969 )
          * ( xassum04v - xassum05v )
endif
```

```
* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) * xgascomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) * xoilcomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
```

```
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) * xcoacomeff / ;
       ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
        (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
        (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
        * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water volume saved **********

* watvolsav start

replace watvolsav ;
   with numecouni * ( - xassum03v ) * 365 / 1000

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with watvolsav * xwatseru

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end
```

```
do comcalc2

*   SECTION  3  -  ECO  specific  calculations  that  override  common
calculations
```

Utilities

The electrical, water, sewer, and central plant systems within an installation are all candidates for energy conservation measures. Energy conservation within utility systems focuses on the reduction of losses in distribution systems, reduction of electrical demand, cogeneration opportunities, and improving system control. The main ECOs used are: installing new and efficient chilers, peak shifting with thermal storage, electrical production with cogeneration, installing energy management systems, and driving pumps with natural gas motors.

The repair of heat distribution lines and manhole sump pumps are two of the most attractive ECOs in this group. This is due to a combination of low capital cost and high savings, resulting in rapid paybacks (less than 1 year). Chiller retrofit paybacks are 4 to 9 years and can also benefit chlorofluorocarbon (CFC) phaseout programs. Replacement chillers may be reduced in capacity (hence, capital cost) if installed in conjunction with other energy conservation measures, such as a lighting or window retrofit. Also, energy management and control systems are proving to not only save energy but to provide a means to monitor energy systems for component failure and degradation. Finally, many opportunities are available for cogeneration and peak shaving when considering gas technologies for electrical production, cooling, or pumping applications.

Energy conservation measures within utilities often involve a high capital cost and a high savings return. This often produces reasonable paybacks if the systems are maintained properly during ther economic life.

Amorphous Core Transformers

Background. Amorphous core transformers save energy because they have lower *no load* losses and also lower *load* losses. The *no load* losses are due to the energizing of the coils inside the transformer. The *load* losses are due to the internal resistance and magnetic field losses. The amorphous core reduces the magnetic field losses when energizing the coils and during loaded conditions.

Amorphous core transformer characteristics. This ECO analyzes installation of amorphous core transformers at each building on an installation.

Amorphous transformer algorithms. The energy savings from amorphous core transformers is due to the reduction in losses compared to iron core transformers. The analysis uses the number of training, administration, family housing, research, medical, barracks, community facility, maintenance/production, and storage buildings on the installation. Using an assumed transformer capacity for each building type results in the total number and size of transformers serving the buildings on an installation. The energy savings from this ECO is a percentage of the transformer's rated capacity. The transformer's size (capacity) is also needed to calculate replacement costs.

Assumptions file.

```
REEP ECO REPORT                                                  Page  1
07/14/94

ECO:  Amorphs Core Transfrmrs
FIELD      DESCRIPTION                                              VALUE
------------------------------------------------------------------------
ECO        Energy Opportunity                    Amorphs Core Transfrmrs
UNIT       Unit                                                     KVAR
ECOTYPE    Energy Opportunity Type                             Utilities
PROGRAM    Rules File (Program) Name                            transfor
CAPCOST    Capital Cost                                            60.00
RECURCOST  Recurring Cost                                           0.00
ECONLIFE   Economic Life                                           20.00
DISCQTY    Discount Quantity                                      250.00
ASSUM01    ECO Assumption 01                            ksf/bldg-Housing
ASSUM01V   ECO Assumption 01 Value                                  1.50
ASSUM02    ECO Assumption 02                 ksf/bldg-Community facility
ASSUM02V   ECO Assumption 02 Value                                 10.20
ASSUM03    ECO Assumption 03                           ksf/bldg-Barracks
ASSUM03V   ECO Assumption 03 Value                                 45.60
ASSUM04    ECO Assumption 04                     ksf/bldg-Administration
ASSUM04V   ECO Assumption 04 Value                                 12.00
ASSUM05    ECO Assumption 05                   ksf/bldg-Hospital/medical
ASSUM05V   ECO Assumption 05 Value                                 16.00
ASSUM06    ECO Assumption 06                            ksf/bldg-Storage
ASSUM06V   ECO Assumption 06 Value                                  5.00
ASSUM07    ECO Assumption 07               ksf/bldg-Maint & prod facility
ASSUM07V   ECO Assumption 07 Value                                  5.00
ASSUM08    ECO Assumption 08                  ksf/bldg-Training facility
ASSUM08V   ECO Assumption 08 Value                                  4.50
ASSUM09    ECO Assumption 09                             KVA cap-Housing
ASSUM09V   ECO Assumption 09 Value                                 25.00
ASSUM10    ECO Assumption 10                  KVA cap-Community facility
ASSUM10V   ECO Assumption 10 Value                                150.00
ASSUM11    ECO Assumption 11                            KVA cap-Barracks
ASSUM11V   ECO Assumption 11 Value                                450.00
ASSUM12    ECO Assumption 12                      KVA cap-Administration
ASSUM12V   ECO Assumption 12 Value                                125.00
```

ASSUM13	ECO Assumption 13	KVA cap-Hospital/medical
ASSUM13V	ECO Assumption 13 Value	250.00
ASSUM14	ECO Assumption 14	KVA cap-Storage
ASSUM14V	ECO Assumption 14 Value	50.00
ASSUM15	ECO Assumption 15	KVA cap-Maint & prod facility
ASSUM15V	ECO Assumption 15 Value	100.00
ASSUM16	ECO Assumption 16	KVA cap-Training facility
ASSUM16V	ECO Assumption 16 Value	75.00
ASSUM17	ECO Assumption 17	No load losses-Trans rated cap
ASSUM17V	ECO Assumption 17 Value	0.00
ASSUM18	ECO Assumption 18	Load losses-Trans. rated cap
ASSUM18V	ECO Assumption 18 Value	0.01

Rules file.

```
* This is the transfor.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with ( ( xfamhouare / xassum01v ;
        * xassum09v ) + ( xcomfacare / xassum02v * ;
        xassum10v ) + ( xbarare / xassum03v * xassum11v ;
        ) + ( xadmare / xassum04v * xassum12v ) + ( ;
        xhosmedare / xassum05v * xassum13v ) + ( xstoare ;
        / xassum06v * xassum14v ) + ( xmaiproare / ;
        xassum07v * xassum15v ) + ( xtraare / xassum08v ;
        * xassum16v ) ) * ( 1 - penfac )

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
   with xcapcost * xlocind * ( ( xfamhouare / xassum01v ;
```

```
        * xassum09v ) + ( xcomfacare / xassum02v * ;
        xassum10v ) + ( xbarare / xassum03v * xassum11v ;
        ) + ( xadmare / xassum04v * xassum12v ) + ( ;
        xhosmedare / xassum05v * xassum13v ) + ( xstoare ;
        / xassum06v * xassum14v ) + ( xmaiproare / ;
        xassum07v * xassum15v ) + ( xtraare / xassum08v ;
        * xassum16v ) ) * prosizfac

* inicos end

********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with ( xassum17v + xassum18v ) * ( ( xfamhouare / ;
        xassum01v * xassum09v ) + ( xcomfacare / ;
        xassum02v * xassum10v ) + ( xbarare / xassum03v ;
        * xassum11v ) + ( xadmare / xassum04v * ;
        xassum12v ) + ( xhosmedare / xassum05v * ;
        xassum13v ) + ( xstoare / xassum06v * xassum14v ;
        ) + ( xmaiproare / xassum07v * xassum15v ) + ( ;
        xtraare / xassum08v * xassum16v ) )

* basdemsav end

******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start
```

```
replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with basdemsav * 24 * 365 * 3.412 / 1000

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved *********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end
```

```
***** Calculate Lbs. of CFCs displaced *****

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common
calculations
```

Direct-Fired Gas Absorption Chillers

Background. Absorption chillers use direct heat to boil a refrigerant from a solution rather than using a compressor. When compared with conventional equipment, absorption chillers have fewer moving parts, no CFCs or HFCs, electrical demand savings, and lower operating pressures. This technology also provides summer load for the gas system and may garner financial incentives from the local utility. Three different size ranges of chillers are considered: 5 to 50 tons, 50 to 100 tons, and more than 100 tons. It is assumed that they always replace older, electric motor chiller systems.

Analysis assumptions. The number of chillers replaced is calculated by dividing the installation's total cooling capacity in the respective range by an assumed chiller size. Electrical savings and the gas cost increase are then determined based on the assumptions above. Economic benefit with respect to CFC replacement has not been calculated; however, the number of pounds displaced is included in the results. The chillers in the 5 to 50 ton range are assumed to be air-cooled.

Uncited sources. Itteilag, Richard, ed.,"A Guide to Natural Gas Cooling" (The American Gas Association, 1994). American Gas Cooling Center, "Natural Gas Cooling Equipment Guide," Second Edition (American Gas Cooling Center, January 1994). Szlenski, T.P., and J.B. Singh, "Comparison of Electric Versus Gas-Fired Cooling Options," *Innovative Energy and Environmental Applications - Proceedings of the 15th World Energy Engineering Congress and 1992 World Environmental Engineering Congress*, 27-31 October 1992.

5 to 50 tons assumptions file.

```
REEP ECO REPORT                                                    Page 1
07/26/94

ECO:  DF NG Chllrs 5-50 Tons

FIELD       DESCRIPTION                                             VALUE
-------------------------------------------------------------------------
ECO         Energy Opportunity                        DF NG Chllrs 5-50 Tons
UNIT        Unit                                                  Chillers
ECOTYPE     Energy Opportunity Type                              Utilities
PROGRAM     Rules File (Program) Name                             childfrs
CAPCOST     Capital Cost                                          30000.00
RECURCOST   Recurring Cost                                            1.00
ECONLIFE    Economic Life                                            20.00
DISCQTY     Discount Quantity                                        10.00
ASSUM01     ECO Assumption 01                        Replacement size [tons]
ASSUM01V    ECO Assumption 01 Value                                  30.00
ASSUM02     ECO Assumption 02                            Cooling Temp. [F]
ASSUM02V    ECO Assumption 02 Value                                  78.00
ASSUM03     ECO Assumption 03                Direct Fired Gas Usage [Btu/ton
ASSUM03V    ECO Assumption 03 Value                               15000.00
ASSUM04     ECO Assumption 04                Direct Fired Elect. Usage [Btu/
ASSUM04V    ECO Assumption 04 Value                                   0.04
ASSUM05     ECO Assumption 05                      Electric Chiller [KW/Ton]
ASSUM05V    ECO Assumption 05 Value                                   1.25
ASSUM06     ECO Assumption 06                  Water Used [gal/ton-hrs] over
ASSUM06V    ECO Assumption 06 Value                                   2.20
ASSUM07     ECO Assumption 07                       Lbls CFC per Ton displaced
ASSUM07V    ECO Assumption 07 Value                                   2.20
ASSUM08     ECO Assumption 08                                        Diversity
```

```
ASSUM08V    ECO Assumption 08 Value                                   0.80
ASSUM09     ECO Assumption 09              % chillers between 5-100 tons
ASSUM09V    ECO Assumption 09 Value                                  35.00
```

5 to 50 tons rules file.

```
* This is the childfrs.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0 .or. xsumdestem - xassum02v < 0
  replace numecouni ;
     with 0
else
  replace numecouni ;
     with ( 1 - penfac ) * xacw5100cap / xassum01v ;
           * ( xassum09v / 100 )
endif

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
    with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end
```

```
********** calculate summer demand saved **********

* sumdemsav start

      replace sumdemsav ;
         with numecouni * ( xassum05v - xassum04v ) * ;
              xassum01v * xassum08v

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with ( 24 * xcdd / ( xsumdestem - xassum02v ) ) * ;
        sumdemsav * 3.412 / 1000

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with -1 * ( 24 * xcdd / ( xsumdestem - xassum02v ) ) ;
        * xassum01v * xassum08v * numecouni * xassum03v ;
        / 1000000

* gasenesav end

********** calculate oil fuel saved **********
```

```
* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with - ( xassum06v * numecouni * xassum01v * ;
          ( 24 * xcdd / ( xsumdestem - xassum02v ) ) ) / 1000


* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with xassum01v * xassum07v * numecouni

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
    with watvolsav * xwatseru

* watcossav end

********** calculate HVAC energy cost saved **********
```

```
* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

50 to 100 tons assumptions file.

```
REEP ECO REPORT                                                    Page 1
07/26/94

ECO:  DF NG Chllrs 50-100 Tons

FIELD        DESCRIPTION                                            VALUE
-------------------------------------------------------------------------
ECO          Energy Opportunity                   DF NG Chllrs 50-100 Tons
UNIT         Unit                                                 Chillers
ECOTYPE      Energy Opportunity Type                             Utilities
PROGRAM      Rules File (Program) Name                            childfrm
CAPCOST      Capital Cost                                         56000.00
RECURCOST    Recurring Cost                                           0.00
ECONLIFE     Economic Life                                           20.00
DISCQTY      Discount Quantity                                        5.00
ASSUM01      ECO Assumption 01                            Replacement Size
ASSUM01V     ECO Assumption 01 Value                                 70.00
ASSUM02      ECO Assumption 02                           Cooling Temp. [F]
ASSUM02V     ECO Assumption 02 Value                                 78.00
ASSUM03      ECO Assumption 03              Direct Fired Gas Usage [Btu/ton
ASSUM03V     ECO Assumption 03 Value                              12000.00
ASSUM04      ECO Assumption 04              Direct Fired Elect. Usage [KW/T
ASSUM04V     ECO Assumption 04 Value                                  0.03
ASSUM05      ECO Assumption 05                     Electric Chiller [KW/Ton]
ASSUM05V     ECO Assumption 05 Value                                  1.25
ASSUM06      ECO Assumption 06                      Water Used [gal/ton-hrs]
ASSUM06V     ECO Assumption 06 Value                                  2.20
ASSUM07      ECO Assumption 07              Lbls CFC per ton cooling displa
ASSUM07V     ECO Assumption 07 Value                                  2.20
ASSUM08      ECO Assumption 08                                   Diversity
ASSUM08V     ECO Assumption 08 Value                                  0.80
ASSUM09      ECO Assumption 09               % chillers between 50-100 tons
ASSUM09V     ECO Assumption 09 Value                                 65.00
```

50 to 100 tons rules file.

```
* This is the childfrm.prg program
```

```
* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0 .or. xsumdestem - xassum02v < 0
  replace numecouni ;
     with 0
else
  replace numecouni ;
     with ( 1 - penfac ) * xacw5100cap / xassum01v ;
           * ( xassum09v / 100 )
endif

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

      replace sumdemsav ;
         with numecouni * ( xassum05v - xassum04v ) * ;
              xassum01v * xassum08v
```

```
* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with ( 24 * xcdd / ( xsumdestem - xassum02v ) ) * ;
         sumdemsav * 3.412 / 1000

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with -1 * ( 24 * xcdd / ( xsumdestem - xassum02v ) ) ;
         * xassum01v * xassum08v * numecouni * xassum03v ;
         / 1000000

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********
```

```
* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with - ( xassum06v * numecouni * xassum01v * ;
          ( 24 * xcdd / ( xsumdestem - xassum02v ) ) ) / 1000

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with xassum01v * xassum07v * numecouni

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
    with watvolsav * xwatseru

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

More than 100 tons assumptions file.

```
REEP ECO REPORT                                                Page 1
07/26/94

ECO:  DF NG Chllrs >100 Tons

FIELD       DESCRIPTION                                         VALUE
---------------------------------------------------------------------
ECO         Energy Opportunity                     DF NG Chllrs >100 Tons
UNIT        Unit                                             Chillers
ECOTYPE     Energy Opportunity Type                         Utilities
PROGRAM     Rules File (Program) Name                        childfrl
CAPCOST     Capital Cost                                    189600.00
RECURCOST   Recurring Cost                                       1.00
ECONLIFE    Economic Life                                       20.00
DISCQTY     Discount Quantity                                    5.00
ASSUM01     ECO Assumption 01                     Replacement size (tons)
ASSUM01V    ECO Assumption 01 Value                            200.00
ASSUM02     ECO Assumption 02                     Cooling temperature (F)
ASSUM02V    ECO Assumption 02 Value                             78.00
ASSUM03     ECO Assumption 03               Direct fired gas usage (Btu/ton
ASSUM03V    ECO Assumption 03 Value                          12000.00
ASSUM04     ECO Assumption 04               Dir. fired elect. usage (kW/ton
ASSUM04V    ECO Assumption 04 Value                              0.26
ASSUM05     ECO Assumption 05                      Electric chiller kW/ton
ASSUM05V    ECO Assumption 05 Value                              1.25
ASSUM06     ECO Assumption 06                     Water Used [gal/ton-hrs]
ASSUM06V    ECO Assumption 06 Value                              2.20
ASSUM07     ECO Assumption 07               Lbls CFC's per Ton cooling disp
ASSUM07V    ECO Assumption 07 Value                              2.20
ASSUM08     ECO Assumption 08                                   Diversity
ASSUM08V    ECO Assumption 08 Value                              0.80
```

More than 100 tons rules file.

```
* This is the childfrl.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0 .or. xsumdestem - xassum02v < 0
```

```
  replace numecouni ;
     with 0
else
  replace numecouni ;
     with ( 1 - penfac ) * xacw100cap / xassum01v
endif

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

      replace sumdemsav ;
         with numecouni * ( xassum05v - xassum04v ) * ;
              xassum01v * xassum08v

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end
```

```
********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with ( 24 * xcdd / ( xsumdestem - xassum02v ) ) * ;
        sumdemsav * 3.412 / 1000

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with -1 * ( 24 * xcdd / ( xsumdestem - xassum02v ) ) ;
        * xassum01v * xassum08v * numecouni * xassum03v ;
        / 1000000

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********
```

```
* watvolsav start

replace watvolsav ;
   with - ( xassum06v * numecouni * xassum01v * ;
          ( 24 * xcdd / ( xsumdestem - xassum02v ) ) ) / 1000

* watvolsav end

********** calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with xassum01v * xassum07v * numecouni

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
    with watvolsav * xwatseru

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Energy Monitoring and Control Systems (EMCS)

Background. Control systems for HVAC systems in existing DOD buildings are typically commercial grade (low-bid) pneumatic systems. These pneumatic control systems are

generally not properly operated and maintained for a various number of reasons, not the least of which is the quality and maintainability of the system. As a result, the HVAC systems in most DOD buildings provide poor occupant comfort and waste considerable energy. Any local controls to save energy are typically unconnected or bypassed. Installing a centralized control system to ensure that various energy saving modes of operation were initiated would save a considerable amount of energy. Also, load management techniques may be applied to such consumers as family housing air conditioning.

Facility assumptions. Application of the EMCS has been analyzed as being applicable to a certain percentage of seven building types. Administrative, barracks, community, training, medical, family housing, and R&D type facilities were considered as candidates for this ECO. The following facility assumptions indicate how each facility type was characterized. Each facility type was analyzed based on its typical physical characteristics and energy consumption (Sliwinski et al., February 1979).

Administrative Bldgs.	
Typical building size (sq ft):	15,000
Number of points:	19
% of total admin space applicable:	55
Heating load (Btu/SF/HDD):	18.97
Cooling season electrical load (kWh/SF):	0.0512
Heating season electrical load (kWh/SF):	0.0215

Barracks	
Typical building size (sq ft):	45,600
Number of points:	45
% of total Barracks space applicable:	40
Heating load (Btu/SF/HDD):	26.27
Cooling load (kWh/SF/CDD):	0.00127
Heating season electrical load (kWh/SF):	0.0215

Community Facility	
Typical building size (sq ft):	10,200
Number of points:	15
% of total Comm'ty space applicable:	80
Heating load (Btu/SF/HDD):	22.97
Cooling season electrical load (kWh/SF):	0.0684
Heating season electrical load (kWh/SF):	0.0682

Training Facility

Typical building size (sq ft):	22,000
Number of points:	30
% of total training space applicable:	30
Heating load (Btu/SF/HDD):	18.97
Cooling season electrical load (kWh/SF):	0.0512
Heating season electrical load (kWh/SF):	0.0215

Medical Facility

Typical building size (sq ft):	16,000
Number of points:	15
% of total medical space applicable:	30
Heating load (Btu/SF/HDD):	24.31
Cooling season electrical load (kWh/SF):	0.0557
Heating season electrical load (kWh/SF):	0.0353

R&D Facility

Typical building size (sq ft):	36,000
Number of points:	45
% of total R&D space applicable:	80
Heating load (Btu/SF/HDD):	18.97
Cooling season electrical load (kWh/SF):	0.0512
Heating season electrical load (kWh/SF):	0.0215

Family Housing

Typical building size (sq ft):	1,500
Number of points:	1
% of total FH space applicable:	90
% of units to be shed at one time:	20
Cooling season peak electrical load (kW):	2.5

All typical building sizes were determined using Fort Hood data. Square footage values were calculated by dividing the total square footage of each building category (per Red Book Tech Data) by the number of buildings in that category (per Integrated Facilities Systems [IFS] data), and then rounding the value to the nearest 100 sq ft. The percentages of applicable buildings were based on the relative square footage that fit the general size and characteristics desired for applying the ECO. Energy use factors for barracks and community facilities were developed using square footage mixes and percentages from Forts Hood, Carson, and Belvoir.

Energy monitoring and control systems conclusions. EMCS have a significant potential for application in DOD buildings. The paybacks are in the medium range and the energy savings large. REEP simple payback periods vary between 5 to 10 years, with an average of about 7.8 years. Single-loop digital control panels will negate most of the savings for an EMCS because of the stricter installation and commissioning practices associated with them. For this reason, SLDC panels have a higher savings than EMCS.

Assumptions file.

REEP ECO REPORT Page 1
07/18/94

ECO: EMCS

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	EMCS
UNIT	Unit	Points
ECOTYPE	Energy Opportunity Type	Utilities
PROGRAM	Rules File (Program) Name	enermoni
CAPCOST	Capital Cost	800.00
RECURCOST	Recurring Cost	0.00
ECONLIFE	Economic Life	10.00
DISCQTY	Discount Quantity	500.00
ASSUM01	ECO Assumption 01	Applicable % of Barracks
ASSUM01V	ECO Assumption 01 Value	40.00
ASSUM02	ECO Assumption 02	Applicable % of Training
ASSUM02V	ECO Assumption 02 Value	30.00
ASSUM03	ECO Assumption 03	Applicable % of Hosp. & Med.
ASSUM03V	ECO Assumption 03 Value	30.00
ASSUM04	ECO Assumption 04	Applicable % of R & D
ASSUM04V	ECO Assumption 04 Value	80.00
ASSUM05	ECO Assumption 05	Applicable % of Community
ASSUM05V	ECO Assumption 05 Value	80.00
ASSUM06	ECO Assumption 06	Applicable % of FH (A/C only)
ASSUM06V	ECO Assumption 06 Value	90.00
ASSUM07	ECO Assumption 07	Applicable % of Administrative
ASSUM07V	ECO Assumption 07 Value	55.00
ASSUM08	ECO Assumption 08	Heating load energy savings
ASSUM08V	ECO Assumption 08 Value	15.00
ASSUM09	ECO Assumption 09	Cooling load energy savings
ASSUM09V	ECO Assumption 09 Value	15.00
ASSUM10	ECO Assumption 10	Points per AHU
ASSUM10V	ECO Assumption 10 Value	15.00
ASSUM11	ECO Assumption 11	Load shedding amount (kW)
ASSUM11V	ECO Assumption 11 Value	2.50
ASSUM12	ECO Assumption 12	Baseline elec. load energy sav
ASSUM12V	ECO Assumption 12 Value	8.00
ASSUM13	ECO Assumption 13	Family Housing Load Shed (%)
ASSUM13V	ECO Assumption 13 Value	20.00

Rules file.

```
* This is the enermoni.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if    xaclogtst = 1
      replace numecouni ;
         with xassum10v * ( 2 * xassum02v / 100 * ;
              xtraare / 22 + 3 * xassum04v / 100 * ;
              xrdtare / 36 + xassum03v / 100 * ;
              xhosmedare / 16 + 1.25 * xassum07v / ;
              100 * xadmare / 15 + 3 * xassum01v / ;
              100 * xbarare / 45.6 + xassum05v / ;
              100 * xcomfacare / 10.2 + ;
              xassum06v / 100 * xfamhouare / 1.5 ) ;
              * ( 1 - penfac )
else
      replace numecouni ;
         with xassum10v * ( 2 * xassum02v / 100 * ;
              xtraare / 22 + 3 * xassum04v / 100 * ;
              xrdtare / 36 + xassum03v / 100 * ;
              xhosmedare / 16 + 1.25 * xassum07v / ;
              100 * xadmare / 15 + 3 * xassum01v ;
              / 100 * xbarare / 45.6 + xassum05v ;
              / 100 * xcomfacare / 10.2 ) ;
              * ( 1 - penfac )
endif

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start
```

```
replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with ( xassum08v / 100 ) / 1000 * xhdd * ( ( ( ;
        xassum02v / 100 ) * xtraare * 18.97 ) + ( ( ;
        xassum04v / 100 ) * xrdtare * 18.97 ) + ( ( ;
        xassum03v / 100 ) * xhosmedare * 24.31 ) + (  ;
        ( xassum07v / 100 ) * xadmare * 18.97 ) + ( ( ;
        xassum01v / 100 ) * xbarare * 26.27 ) + ( ( ;
        xassum05v / 100 ) * xcomfacare * 22.97 ) )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

if xaclogtst = 1
      replace cooenesav ;
         with ( ( ( xassum09v / 100 ) * xcdd * 0.001275 + ;
              ( xassum12v / 100 ) * ( 365 - xheaseaday - ;
              xcooseaday ) * 0.0152 ) * ( ;
              xassum01v / 100 ) * 3.412 * xbarare ) + ( ;
              xassum09v / 100 ) * xcooseaday * 3.412 * ( ( ( ;
              xassum02v / 100 ) * xtraare * 0.0512 ) + ( ;
              ( xassum04v / 100 ) * xrdtare * 0.0512 ) + ;
              ( ( xassum03v / 100 ) * xhosmedare * 0.0557 ;
              ) + ( ( xassum07v / 100 ) * xadmare * 0.0512 ;
              ) + ( ( xassum05v / 100 ) * xcomfacare * ;
              0.0684 ) ) + ( xassum12v / 100 ) * ( 365 - ;
              xheaseaday ) * 3.412 * ( ( ( xassum02v / 100 ) ;
              * xtraare * 0.0215 ) + ( ( xassum04v / 100 ) ;
              * xrdtare * 0.0215 ) + ( ( xassum03v / 100 ) * ;
              xhosmedare * 0.0353 ) + ( ( xassum07v / 100 ;
              ) * xadmare * 0.0215 ) + ( ( xassum05v / 100 ;
              ) * xcomfacare * 0.0662 ) )
else
      replace cooenesav ;
         with ( ( xassum12v / 100 ) * ( 365 - xheaseaday ) ;
              * 3.412 ) * ( ( ( xassum01v / 100 ) * xbarare ;
              * .0152 ) + ( ( xassum02v ;
              / 100 ) * xtraare * 0.0215 ) + ( ( xassum04v ;
```

```
                 / 100 ) * xrdtare * 0.0215 ) + ( ( xassum03v ;
                 / 100 ) * xhosmedare * 0.0353 ) + ( ( xassum07v ;
                 / 100 ) * xadmare * 0.0215 ) + ( ( xassum05v ;
                 / 100 ) * xcomfacare * 0.0662 ) )
endif

* cooenesav end

********** calculate baseload demand saved **********

* basdemsav start

            replace basdemsav ;
                  with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

      if xaclogtst = 1
            replace sumdemsav ;
                  with xassum11v * ( xassum13v / 100 ) * ;
                  xfamhouare / 1.5
      else
            replace sumdemsav ;
                  with 0
endif

* sumdemsav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with cooenesav

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

x = xghp35con + xohp35con + xchp35con + xghp7535con + ;
    xohp7535con + xchp7535con
if x = 0
```

```
        replace gasenesav ;
           with 0
else
        replace gasenesav ;
           with heaenesav * ( xghp35con + xghp7535con ) / ( ;
                xghp35con + xohp35con + xchp35con + ;
                xghp7535con + xohp7535con + xchp7535con )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

x = xghp35con + xohp35con + xchp35con + xghp7535con + ;
    xohp7535con + xchp7535con
if x = 0
        replace oilenesav ;
           with 0
else
        replace oilenesav ;
           with heaenesav * ( xohp35con + xohp7535con ) / ( ;
                xghp35con + xohp35con + xchp35con + ;
                xghp7535con + xohp7535con + xchp7535con )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

x = xghp35con + xohp35con + xchp35con + xghp7535con + ;
    xohp7535con + xchp7535con
if x = 0
        replace coaenesav ;
           with 0
else
        replace coaenesav ;
           with heaenesav * ( xchp35con + xchp7535con ) / ( ;
                xghp35con + xohp35con + xchp35con + ;
                xghp7535con + xohp7535con + xchp7535con )
endif

* coaenesav end

********** calculate water volume saved **********
```

```
* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Gas Engine-Driven Chillers

Background. A gas engine-driven chiller uses the same cooling process as a conventional electric-powered system except the electric motor is replaced by an engine. This engine provides variable-speed operation, higher part-load efficiency, and waste-heat recovery. Switching to natural gas from electricity can reduce summer peak electrical demand,

and provides a summer gas load that may bring financial incentives from the local natural gas utility. This analysis does not consider the benefits of waste-heat recovery for domestic hot water use or steam generation. Three different size ranges of gas engine-driven chillers are considered: 5 to 50 tons, 50 to 100 tons, and more than 100 tons. It is assumed that they always replace older, electric motor chiller systems. The common chiller assumptions and the size-specific assumptions are shown below.

Analysis assumptions. The number of chillers replaced is calculated by dividing the installation's total cooling capacity in the respective range by an assumed chiller size. Electrical savings and the gas cost increase are then determined based on the assumptions above. Economic benefit with respect to CFC replacement has not been calculated; however, the number of pounds displaced is included in the results. The chillers in the 5 to 50 ton range are assumed to be air-cooled.

Uncited sources. Itteilag, Richard, ed., "A Guide to Natural Gas Cooling" (The American Gas Association 1994). American Gas Cooling Center, "Natural Gas Cooling Equipment Guide" Second Edition (American Gas Cooling Center, January 1994). Szlenski, T.P., and J.B. Singh, "Comparison of Electric Versus Gas-Fired Cooling Options," *Innovative Energy and Environmental Applications - Proceedings of the 15th World Energy Engineering Congress and 1992 World Environmental Engineering Congress*, 27-31 October 1992.

5 to 50 tons assumptions file.

```
REEP ECO REPORT                                              Page 1
07/26/94

ECO:  GasEng Chllrs 5-50 Tons
FIELD       DESCRIPTION                                       VALUE
-------------------------------------------------------------------
ECO         Energy Opportunity                GasEng Chllrs 5-50 Tons
UNIT        Unit                                             Chillers
ECOTYPE     Energy Opportunity Type                         Utilities
PROGRAM     Rules File (Program) Name                        chilgass
CAPCOST     Capital Cost                                     25500.00
RECURCOST   Recurring Cost                                       2.90
ECONLIFE    Economic Life                                       20.00
DISCQTY     Discount Quantity                                   10.00
ASSUM01     ECO Assumption 01                Replacement Size [Tons]
ASSUM01V    ECO Assumption 01 Value                             30.00
ASSUM02     ECO Assumption 02                Cooling Temperature [F]
ASSUM02V    ECO Assumption 02 Value                             78.00
ASSUM03     ECO Assumption 03                    Gas Usage [Btu/Ton]
ASSUM03V    ECO Assumption 03 Value                          12000.00
ASSUM04     ECO Assumption 04                Electric Usage [KW/Ton]
```

ASSUM04V	ECO Assumption 04 Value	0.10
ASSUM05	ECO Assumption 05	Electric Chiller [KW/Ton]
ASSUM05V	ECO Assumption 05 Value	1.25
ASSUM06	ECO Assumption 06	Water Usage [gal/ton-hrs]
ASSUM06V	ECO Assumption 06 Value	0.30
ASSUM07	ECO Assumption 07	Lbls CFC per ton cooling displa
ASSUM07V	ECO Assumption 07 Value	2.20
ASSUM08	ECO Assumption 08	Diversity
ASSUM08V	ECO Assumption 08 Value	0.80
ASSUM09	ECO Assumption 09	% chillers in 5-50 ton range
ASSUM09V	ECO Assumption 09 Value	35.00

5 to 50 tons rules file.

```
* This is the chilgass.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0 .or. xsumdestem - xassum02v < 0
  replace numecouni ;
     with 0
else
  replace numecouni ;
     with ( 1 - penfac ) * xacw5100cap / xassum01v ;
           * ( xassum09v / 100 )
endif

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end
```

```
********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

      replace sumdemsav ;
         with numecouni * ( xassum05v - xassum04v ) * ;
              xassum01v * xassum08v

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with ( 24 * xcdd / ( xsumdestem - xassum02v ) ) * ;
        sumdemsav * 3.412 / 1000

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start
```

```
replace gasenesav ;
   with -1 * ( 24 * xcdd / ( xsumdestem - xassum02v ) ) ;
        * xassum01v * xassum08v * numecouni * xassum03v ;
        / 1000000

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with - ( xassum06v * numecouni * xassum01v * ;
          ( 24 * xcdd / ( xsumdestem - xassum02v ) ) ) / 1000

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with xassum07v * xassum01v * numecouni

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start
```

```
replace watcossav ;
    with watvolsav * xwatseru

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

50 to 100 tons assumptions file.

REEP ECO REPORT Page 1
07/26/94

ECO: GasEng Chllrs 50-100 Tons

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	GasEng Chllrs 50-100 Tons
UNIT	Unit	Chillers
ECOTYPE	Energy Opportunity Type	Utilities
PROGRAM	Rules File (Program) Name	chilgasm
CAPCOST	Capital Cost	52500.00
RECURCOST	Recurring Cost	2.90
ECONLIFE	Economic Life	20.00
DISCQTY	Discount Quantity	5.00
ASSUM01	ECO Assumption 01	Replacement Size [Tons]
ASSUM01V	ECO Assumption 01 Value	70.00
ASSUM02	ECO Assumption 02	Cooling Temp. [F]
ASSUM02V	ECO Assumption 02 Value	78.00
ASSUM03	ECO Assumption 03	Gas Usage [Btu/ton]
ASSUM03V	ECO Assumption 03 Value	8600.00
ASSUM04	ECO Assumption 04	Electric Usage [KW/ton]
ASSUM04V	ECO Assumption 04 Value	0.02
ASSUM05	ECO Assumption 05	Electric Chiller [KW/ton]
ASSUM05V	ECO Assumption 05 Value	1.25
ASSUM06	ECO Assumption 06	Water Usage [gal/ton-hrs]
ASSUM06V	ECO Assumption 06 Value	0.30
ASSUM07	ECO Assumption 07	Lbls CFC per Ton Cooling displa
ASSUM07V	ECO Assumption 07 Value	2.20
ASSUM08	ECO Assumption 08	Diversity
ASSUM08V	ECO Assumption 08 Value	0.80

```
ASSUM09     ECO Assumption 09            % chillers between 50-100 tons
ASSUM09V    ECO Assumption 09 Value                               65.00
```

50 to 100 tons rules file.

```
* This is the chilgasm.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0 .or. xsumdestem - xassum02v < 0
  replace numecouni ;
     with 0
else
  replace numecouni ;
     with ( 1 - penfac ) * xacw5100cap/ xassum01v ;
           * ( xassum09v / 100 )
endif

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0
```

```
* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

      replace sumdemsav ;
         with numecouni * ( xassum05v - xassum04v ) * ;
              xassum01v * xassum08v

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with ( 24 * xcdd / ( xsumdestem - xassum02v ) ) * ;
        sumdemsav * 3.412 / 1000

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with -1 * ( 24 * xcdd / ( xsumdestem - xassum02v ) ) ;
        * xassum01v * xassum08v * numecouni * xassum03v ;
        / 1000000
```

```
* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with - ( xassum06v * numecouni * xassum01v * ;
         ( 24 * xcdd / ( xsumdestem - xassum02v ) ) ) / 1000


* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with xassum07v * xassum01v * numecouni

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start
```

```
replace watcossav ;
    with watvolsav * xwatseru

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

More than 100 tons assumptions file.

```
REEP ECO REPORT                                                  Page 1
07/26/94

ECO:  GasEng Chllrs >100 Tons
FIELD      DESCRIPTION                                            VALUE
-----------------------------------------------------------------------
ECO        Energy Opportunity                      GasEng Chllrs >100 Tons
UNIT       Unit                                                   Chillers
ECOTYPE    Energy Opportunity Type                               Utilities
PROGRAM    Rules File (Program) Name                              chilgasl
CAPCOST    Capital Cost                                          160000.00
RECURCOST  Recurring Cost                                             2.90
ECONLIFE   Economic Life                                             20.00
DISCQTY    Discount Quantity                                          5.00
ASSUM01    ECO Assumption 01                        Replacement Size [tons]
ASSUM01V   ECO Assumption 01 Value                                  200.00
ASSUM02    ECO Assumption 02                        Cooling Temperature [F]
ASSUM02V   ECO Assumption 02 Value                                   78.00
ASSUM03    ECO Assumption 03                             Gas Usage [Btu/ton]
ASSUM03V   ECO Assumption 03 Value                                 9300.00
ASSUM04    ECO Assumption 04                        Electric Usage [KW/ton]
ASSUM04V   ECO Assumption 04 Value                                    0.18
ASSUM05    ECO Assumption 05                      Electric Chiller [KW/ton]
ASSUM05V   ECO Assumption 05 Value                                    1.25
ASSUM06    ECO Assumption 06                      Water Usage [gal/ton-hrs]
ASSUM06V   ECO Assumption 06 Value                                    0.30
ASSUM07    ECO Assumption 07                Lbls CFC per Ton cooling displa
ASSUM07V   ECO Assumption 07 Value                                    2.20
ASSUM08    ECO Assumption 08                                     diversity
ASSUM08V   ECO Assumption 08 Value                                    0.80
```

More than 100 tons rules file.

```
* This is the chilgasl.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0 .or. xsumdestem - xassum02v < 0
  replace numecouni ;
     with 0
else
  replace numecouni ;
     with ( 1 - penfac ) * xacw100cap / xassum01v
endif

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end
```

```
********** calculate summer demand saved **********

* sumdemsav start

      replace sumdemsav ;
         with numecouni * ( xassum05v - xassum04v ) * ;
              xassum01v * xassum08v

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with ( 24 * xcdd / ( xsumdestem - xassum02v ) ) * ;
        sumdemsav * 3.412 / 1000

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with -1 * ( 24 * xcdd / ( xsumdestem - xassum02v ) ) ;
        * xassum01v * xassum08v * numecouni * xassum03v ;
        / 1000000

* gasenesav end
```

```
********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with - ( xassum06v * numecouni * xassum01v * ;
          ( 24 * xcdd / ( xsumdestem - xassum02v ) ) ) / 1000

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with xassum07v * xassum01v * numecouni

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
    with watvolsav * xwatseru

* watcossav end
```

```
********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

High Efficiency Electric Chiller

Background. Large chillers located in central energy plants use a significant amount of the Army's electrical energy. This ECO calculates the savings resulting from the replacement of old electric chillers with new, higher efficiency electric chillers that are non-CFC based.

Analysis assumptions. The number of chillers assumed to be replaced is calculated by dividing the installation's total cooling capacity by an assumed chiller size. Electrical savings are then determined based on the assumptions above. Economic benefit with respect to CFC replacement has not been calculated; however, the number of pounds displaced is included in the results.

Uncited sources. Szlenski, T.P., and J.B. Singh "Comparison of Electric Versus Gas-Fired Cooling Options," *Innovative Energy and Environmental Applications - Proceedings of the 15th World Energy Engineering Congress and 1992 World Environmental Engineering Congress,* 27-31 October 1992.

5 to 50 tons assumptions file.

```
REEP ECO REPORT                                                    Page 1
07/26/94

ECO:  HiEff Chllrs 5-50 Tons

FIELD       DESCRIPTION                                             VALUE
-------------------------------------------------------------------------
ECO         Energy Opportunity                      HiEff Chllrs 5-50 Tons
UNIT        Unit                                                  Chillers
ECOTYPE     Energy Opportunity Type                              Utilities
PROGRAM     Rules File (Program) Name                             chilhefs
CAPCOST     Capital Cost                                          18000.00
```

RECURCOST	Recurring Cost	0.00
ECONLIFE	Economic Life	20.00
DISCQTY	Discount Quantity	10.00
ASSUM01	ECO Assumption 01	Old Chiller KW/Ton
ASSUM01V	ECO Assumption 01 Value	1.50
ASSUM02	ECO Assumption 02	New Chiller KW/Ton
ASSUM02V	ECO Assumption 02 Value	1.30
ASSUM03	ECO Assumption 03	Replacement Size [Tons]
ASSUM03V	ECO Assumption 03 Value	30.00
ASSUM04	ECO Assumption 04	Cooling Temp. [F]
ASSUM04V	ECO Assumption 04 Value	78.00
ASSUM05	ECO Assumption 05	Lbls CFC per Ton Cooling displa
ASSUM05V	ECO Assumption 05 Value	2.20
ASSUM06	ECO Assumption 06	Diversity
ASSUM06V	ECO Assumption 06 Value	0.80
ASSUM07	ECO Assumption 07	% chillers between 5-50 tons
ASSUM07V	ECO Assumption 07 Value	35.00

5 to 50 tons rules file:

```
* This is the chilhefs.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

  replace numecouni ;
     with ( 1 - penfac ) * xacw5100cap / xassum03v ;
           * ( xassum07v / 100 )

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end
```

```
********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

if     xsumdestem - xassum04v > 0
       replace sumdemsav ;
          with numecouni * ( xassum01v - xassum02v ) * ;
               xassum03v * xassum06v
else
       replace sumdemsav ;
          with 0
endif

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with ( 24 * xcdd / ( xsumdestem - xassum04v ) ) * ;
        sumdemsav * 3.412 / 1000

* eleenesav end
```

```
********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with xassum05v * xassum03v * numecouni

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1
```

```
********** calculate water cost saved **********

* watcossav start

replace watcossav ;
    with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

50 - 100 tons assumptions file.

```
REEP ECO REPORT                                                   Page 1
07/26/94

ECO:  HiEff Chllrs 50-100 Tons
```

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	HiEff Chllrs 50-100 Tons
UNIT	Unit	Chillers
ECOTYPE	Energy Opportunity Type	Utilities
PROGRAM	Rules File (Program) Name	chilhefm
CAPCOST	Capital Cost	42000.00
RECURCOST	Recurring Cost	0.00
ECONLIFE	Economic Life	20.00
DISCQTY	Discount Quantity	5.00
ASSUM01	ECO Assumption 01	Old Chiller KW/Ton
ASSUM01V	ECO Assumption 01 Value	1.30
ASSUM02	ECO Assumption 02	New Chiller KW/Ton
ASSUM02V	ECO Assumption 02 Value	1.00
ASSUM03	ECO Assumption 03	Replacement Size [Tons]
ASSUM03V	ECO Assumption 03 Value	70.00
ASSUM04	ECO Assumption 04	Cooling Temp. [F]
ASSUM04V	ECO Assumption 04 Value	78.00
ASSUM05	ECO Assumption 05	Lbls CFC per Ton Cooling displa
ASSUM05V	ECO Assumption 05 Value	2.20
ASSUM06	ECO Assumption 06	Diversity
ASSUM06V	ECO Assumption 06 Value	0.80

```
ASSUM07     ECO Assumption 07            % chillers between 50-100 tons
ASSUM07V    ECO Assumption 07 Value                               65.00
```

50 to 100 tons rules file.

```
* This is the chilhefm.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

  replace numecouni ;
     with ( 1 - penfac ) * xacw5100cap / xassum03v ;
          * ( xassum07v / 100 )

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

if     xsumdestem - xassum04v > 0
       replace sumdemsav ;
```

```
          with numecouni * ( xassum01v - xassum02v ) * ;
               xassum03v * xassum06v
else
      replace sumdemsav ;
          with 0
endif

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with ( 24 * xcdd / ( xsumdestem - xassum04v ) ) * ;
        sumdemsav * 3.412 / 1000

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start
```

```
replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with xassum05v * xassum03v * numecouni

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
    with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0
```

```
* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

More than 100 tons assumptions file.

```
REEP ECO REPORT                                                      Page 1
07/26/94

ECO:  HiEff Chllrs >100 Tons
FIELD       DESCRIPTION                                              VALUE
---------------------------------------------------------------------------
ECO         Energy Opportunity                         HiEff Chllrs >100 Tons
UNIT        Unit                                                     Chillers
ECOTYPE     Energy Opportunity Type                                 Utilities
PROGRAM     Rules File (Program) Name                                chilhefl
CAPCOST     Capital Cost                                            120000.00
RECURCOST   Recurring Cost                                               0.00
ECONLIFE    Economic Life                                               20.00
DISCQTY     Discount Quantity                                            5.00
ASSUM01     ECO Assumption 01                                 Old Chiller KW/Ton
ASSUM01V    ECO Assumption 01 Value                                      1.25
ASSUM02     ECO Assumption 02                                 New Chiller KW/Ton
ASSUM02V    ECO Assumption 02 Value                                      0.80
ASSUM03     ECO Assumption 03                          Replacement Size [Tons]
ASSUM03V    ECO Assumption 03 Value                                    200.00
ASSUM04     ECO Assumption 04                          Cooling Temperature [F]
ASSUM04V    ECO Assumption 04 Value                                     78.00
ASSUM05     ECO Assumption 05                    Lbls CFC per Ton cooling displa
ASSUM05V    ECO Assumption 05 Value                                      2.20
ASSUM06     ECO Assumption 06                                       Diversity
ASSUM06V    ECO Assumption 06 Value                                      0.80
```

More than 100 tons rules file.

```
* This is the chilhefl.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

  replace numecouni ;
     with ( 1 - penfac ) * xacw100cap / xassum03v
```

```
* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

if     xsumdestem - xassum04v > 0
       replace sumdemsav ;
          with numecouni * ( xassum01v - xassum02v ) * ;
               xassum03v * xassum06v
else
       replace sumdemsav ;
          with 0
endif

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start
```

```
replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with ( 24 * xcdd / ( xsumdestem - xassum04v ) ) * ;
        sumdemsav * 3.412 / 1000

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end
```

```
********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with xassum05v * xassum03v * numecouni

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
    with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Manhole Sump-Pump Inspection/Repair Program

Background. When sufficient water accumulates in a manhole, energy is wasted in the unintentional production of steam, which then vents directly to the atmosphere. The reason for this accumulation is generally a combination of rain, runoff, or ground water ingress into the manhole coupled with an inoperative sump pump. Given the variety of systems found in the Army and a lack of hard experimental data (e.g., measured heat loss from a flooded conduit system, or, accurate leak incidence data), these calculations are necessarily approximate.

Manhole sump pump characteristics. The cost to replace a sump pump can be as much as $300 for parts and labor. If instead only minor repairs are needed (e.g., clear the pump inlet, adjust or replace the float mechanism, replace the switch, or return

electrical power), a cost for labor of approximately $100 may be needed. For a manhole with an inoperative sump pump and accumulated water, it is possible to estimate the amount of excess energy lost. Assume that 10 gal. of water is converted to steam each hour. This represents an energy loss of 80,966 Btu/hr. If the sump pump goes unrepaired for 6 months (4320 hours) and energy costs $5/MBtu, then the cost of the wasted energy is $1,750. In addition, a number of manhole internal components will be severely degraded.

Manhole losses (MBtu/hr):	0.081
Line losses (MBtu/hr):	0.048
Capital cost per unit ($):	900
Recurring cost (% of IC):	74
Economic life (yr):	20

Facility assumptions. A conservative method to estimate the number of manholes on an installation is to divide the total length of piping by 500 ft. According to the Corps of Engineers Guide Specification, this is the maximum allowed distance between manholes. The frequency of sump pumps becoming inoperative is not well known. At a FEAP demonstration project at Fort Jackson, SC, with repeated inspections of a relatively new system, an average of as many as 53 percent of the sump pumps were found to be inoperative. In contrast, other installations may have very few problems with sump pumps. A guess for an Army-wide figure, considering age, maintenance budgets, and ground water conditions, would be 10 to 20 percent. An important point here is that a preventative program would require inspection of all the manholes. Otherwise, steaming is generally the only sign and should be viewed as an alarm signal.

Distance between manholes (kft):	0.50
Percentage failed (%):	15
Time pumps failed (hr/hr):	4,320
Time line energized (hr/hr):	8,760

Manhole sump pump algorithms.

$$\text{Heating Savings (MBtu/yr)} = Q_{op} \times (ML \times Hrs_{pump} + LL \times Hrs_{eng})$$

where:

Q_{op} = Number of opportunities

ML = Manhole losses = 0.081 MBtu/hr

Hrs_{pump} = Annual number of hours that pumps failed (assumed to be 6 months)

LL = Distribution line losses

Hrs_{eng} = Annual hours that distribution lines are energized (assumed to be year-round)

Manhole sump pump conclusions. Due to the phenomenal amount of energy wasted when manhole sumps malfunction, and the relatively low cost of repairing them, payback periods are very short for this type of repair/maintenance. Although the energy savings of this ECO are minor when compared to the overall amount of energy the Army consumes, this ECO should be instituted due to its rapid payback period.

Assumptions file.

```
REEP ECO REPORT                                                   Page 1
09/01/94

ECO:  Manhl Sump-Pmp I/R Prgrm

FIELD       DESCRIPTION                                            VALUE
-------------------------------------------------------------------------
ECO         Energy Opportunity                       Manhl Sump-Pmp I/R Prgrm
UNIT        Unit                                                   Units
ECOTYPE     Energy Opportunity Type                            Utilities
PROGRAM     Rules File (Program) Name                           manhsump
CAPCOST     Capital Cost                                          900.00
RECURCOST   Recurring Cost                                         74.00
ECONLIFE    Economic Life                                          20.00
DISCQTY     Discount Quantity                                      50.00
ASSUM01     ECO Assumption 01              Distance between Manholes (kft)
ASSUM01V    ECO Assumption 01 Value                                 0.50
ASSUM02     ECO Assumption 02                          % of sump pump failure
ASSUM02V    ECO Assumption 02 Value                                15.00
ASSUM03     ECO Assumption 03                     Time pumps failed (hrs/yr)
ASSUM03V    ECO Assumption 03 Value                              4320.00
ASSUM04     ECO Assumption 04                   Time line energized (hrs/yr)
ASSUM04V    ECO Assumption 04 Value                              8760.00
ASSUM05     ECO Assumption 05                       Manhole losses (MBtu/hr)
ASSUM05V    ECO Assumption 05 Value                                 0.08
ASSUM06     ECO Assumption 06                          Line losses (MBtu/hr)
ASSUM06V    ECO Assumption 06 Value                                 0.05
```

Rules file.

```
* This is the manhsump.prg program
```

```
* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if      xshwpip > 0
        replace numecouni ;
           with ( 1 - penfac ) * xshwpip / xassum01v ;
                    * ( xassum02v / 100 )
else
        replace numecouni ;
           with 0
endif

* numecouni end

********** Select Project Size Factor ******

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with xcapcost * xlocind * numecouni * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
  with 0
```

```
* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * ( ( xassum05v * xassum03v ) + ( ;
        xassum06v * xassum04v ) )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with 0

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

x = xghp35con + xohp35con + xchp35con
if x = 0
        replace gasenesav ;
           with 0
else
        replace gasenesav ;
           with ( xghp35con ) * xgascomeff / ;
             ((( xghp35con ) * xgascomeff ) + ;
             (( xohp35con ) * xoilcomeff ) + ;
             (( xchp35con ) * xcoacomeff )) ;
             * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end
```

```
********** calculate oil fuel saved **********

* oilenesav start

x = xghp35con + xohp35con + xchp35con
if x = 0
        replace oilenesav ;
           with 0
else
        replace oilenesav ;
           with ( xohp35con ) * xoilcomeff / ;
             ((( xghp35con ) * xgascomeff ) + ;
             (( xohp35con ) * xoilcomeff ) + ;
             (( xchp35con ) * xcoacomeff )) ;
             * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

x = xghp35con + xohp35con + xchp35con
if x = 0
        replace coaenesav ;
           with 0
else
        replace coaenesav ;
           with ( xchp35con ) * xcoacomeff / ;
             ((( xghp35con ) * xgascomeff ) + ;
             (( xohp35con ) * xoilcomeff ) + ;
             (( xchp35con ) * xcoacomeff )) ;
             * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********
```

```
* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Cool Storage

Background. Storage cooling technologies shift the electrical demand for air conditioning from on-peak to off-peak periods. The reduction of on-peak electrical demand results in significant savings in demand charges. Effective application of thermal storage technology depends on the utility rate structure, the system capital costs, and the hourly profile of the cooling load at the installation. Two types of storage cooling systems are available; one stores chilled water and the other stores ice. A previous study shows that it is generally practical to shift about 5 percent of the peak demand using large chillers (more than 25 tons capacity) (Sohn and Cler 1989).

Cool storage characteristics. The cost of storage cooling systems is typically expressed in terms of dollars per storage capacity, expressed in ton-hours ($/ton-hr). Storage

cooling system costs vary considerably depending on whether it is new construction, a replacement application, or a retrofit requiring a new condensing unit. The application in this study is for retrofit and is in the highest cost category. Capital costs for retrofit of either chilled water storage or ice storage are roughly the same and range from $100 to $300 per ton-hour, but are reducing as the technology matures. A realistic cost of $125/ton-hr is shown below and used for this analysis.

Facility assumptions. The amount of energy to be stored and thus the size of a storage cooling system is a function of how much demand is to be shifted and for how long. This amount is limited by the number of large chillers available on the installation and what is practical to accomplish. It may be practical to shift more peak for a longer period than assumed below, but this should be the subject of a specific optimization study for that specific installation. If the criteria below works, then further investigation is warranted.

Cool storage conclusions. Based on the analysis, storage cooling systems exhibit significant potential for demand savings, but are only cost effective where the utilities rate structure results in a high annual demand charge. Retrofitting storage cooling has the highest capital costs (incorporating storage cooling into new construction costs only half what a retrofit costs) and the Army pays, in general, a low price for electricity, both for demand and energy. Ratchet clauses play a major role here also. Thermal storage is a prime candidate for demand side management and once that is incorporated into the economics, the results will change. Note that this is a retrofit analysis and retrofitting is much more costly than upgrading during replacements and incorporating storage cooling into new construction.

Assumptions file.

```
REEP ECO REPORT                                                  Page 1
09/01/94

ECO:  Storage Cooling Systems

FIELD       DESCRIPTION                                           VALUE
------------------------------------------------------------------------
ECO         Energy Opportunity                    Storage Cooling Systems
UNIT        Unit                                               Ton-Hours
ECOTYPE     Energy Opportunity Type                            Utilities
PROGRAM     Rules File (Program) Name                           coolstor
CAPCOST     Capital Cost                                          125.00
RECURCOST   Recurring Cost                                          1.00
ECONLIFE    Economic Life                                          15.00
DISCQTY     Discount Quantity                                    5000.00
ASSUM01     ECO Assumption 01                       Capacity effected (%)
ASSUM01V    ECO Assumption 01 Value                                75.00
```

ASSUM02	ECO Assumption 02	Length on-peak shift (hrs)
ASSUM02V	ECO Assumption 02 Value	4.00
ASSUM03	ECO Assumption 03	Average chiller dem. (kW/ton)
ASSUM03V	ECO Assumption 03 Value	0.70
ASSUM04	ECO Assumption 04	Demand shift (%)
ASSUM04V	ECO Assumption 04 Value	5.00

Rules file.

```
* This is the coolstor.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with min ( ( 1 - penfac ) * ( xacw100cap * ;
                  ( xassum01v / 100 ) + xacw5100cap * 0.5 ) ;
                  * xassum02v , ( 1 - penfac ) * ( xassum04v ;
                  / 100 ) * xelekwpdem * xassum02v / xassum03v )

* numecouni end

********** Select Project Size Factors *****

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with xcapcost * xlocind * numecouni * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end
```

```
********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
   with min ( xassum03v * ( 1 - penfac ) * ;
            ( xassum01v / 100 ) * ( xacw100cap + xacw5100cap ;
            * 0.5 ) , ( 1 - penfac ) * ( xassum04v / 100 ) * ;
            xelekwpdem )

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

replace eleenesav ;
   with 0

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start
```

```
replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved ***********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved *********

* henecossav start

replace henecossav ;
   with 0
```

```
* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Underground Heat Distribution System Leak Repairs

Background. When a leak occurs in an underground heat distribution system, secondary steaming is often observed. This steaming is either from groundwater leaking into the conduited systems and destroying the insulation or from media loss itself if the carrier pipe is perforated. In either case, considerable heat loss is occuring along with system damage. Given the variety of systems found in the Army and a lack of hard experimental data (e.g., measured heat loss from a flooded conduit system, or, accurate leak incidence data), these calculations are necessarily approximate.

Leak repair characteristics. The costs to locate and repair a leak in a buried underground heat distribution system is estimated to be $4,085. This includes materials, labor, and equipment. For an underground distribution system with a leak, it is possible to estimate the amount of excess energy lost by assuming that the transmission heat loss is five times the design rating. Assuming a design value of 80 Btu/ft-hr and a typical length between manholes of 500 ft, this represents an excess energy loss of 160,000 Btu/hr. If the leak is unrepaired for 6 months (4320 hours) and energy costs $3/MBtu, then the cost of the wasted energy is $2,074. In addition a number of manhole internal components will be severely degraded.

Excess Line losses (MBtu/hr):	0.16
Capital Cost per unit ($):	4,085
Recurring Cost (% of IC):	0
Economic Life (yr):	20

Facility assumptions. The frequency of sump pumps becoming inoperative is not well known. A conservative method to estimate the number of leaks on an installation is to multiply the total length of piping on an installation by 0.0795 leaks/yr-thousand linear ft (Pan Am World Services, Inc., June 1985).

Failure rate (leaks/yr-klf):	0.0795
Time line energized (hr/yr):	8760

Assumptions file.

```
REEP ECO REPORT                                                    Page 1
09/01/94

ECO:  Undrgrnd Heat Dist Sys Rprs

FIELD       DESCRIPTION                                             VALUE
------------------------------------------------------------------------
ECO         Energy Opportunity              Undrgrnd Heat Dist Sys Rprs
UNIT        Unit                                                Repairs
ECOTYPE     Energy Opportunity Type                           Utilities
PROGRAM     Rules File (Program) Name                          heatrepa
CAPCOST     Capital Cost                                        4085.00
RECURCOST   Recurring Cost                                         0.00
ECONLIFE    Economic Life                                         20.00
DISCQTY     Discount Quantity                                     20.00
ASSUM01     ECO Assumption 01             Leaks per klf in buried system
ASSUM01V    ECO Assumption 01 Value                                0.08
ASSUM02     ECO Assumption 02                Time line energized (hours)
ASSUM02V    ECO Assumption 02 Value                             8760.00
ASSUM03     ECO Assumption 03                      Line losses (MBtu/hr)
ASSUM03V    ECO Assumption 03 Value                                0.16
```

Rules file.

```
* This is the heatrepa.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if                       xshwpip > 0
                         replace numecouni ;
                            with ( 1 - penfac ) * xshwpip * xassum01v
else
                         replace numecouni ;
                            with 0
endif

* numecouni end


********** Select Project Size Factor *******
```

```
do comcalc0

********** calculate initial cost ***********

* inicos start

replace inicos ;
   with xcapcost * xlocind * numecouni * prosizfac

* inicos end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
  with 0

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * xassum03v * xassum02v

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start
```

```
replace eleenesav ;
   with 0

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

x = xghp35con + xohp35con + xchp35con
if x = 0
                        replace gasenesav ;
                           with 0
else
                        replace gasenesav ;
                           with ( xghp35con ) * xgascomeff / ;
                        ((( xghp35con ) * xgascomeff ) + ;
                        (( xohp35con ) * xoilcomeff ) + ;
                        (( xchp35con ) * xcoacomeff )) ;
                        * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

x = xghp35con + xohp35con + xchp35con
if x = 0
                        replace oilenesav ;
                           with 0
else
                        replace oilenesav ;
                           with ( xohp35con ) * xoilcomeff / ;
                        ((( xghp35con ) * xgascomeff ) + ;
                        (( xohp35con ) * xoilcomeff ) + ;
                        (( xchp35con ) * xcoacomeff )) ;
                        * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

x = xghp35con + xohp35con + xchp35con
if x = 0
                        replace coaenesav ;
                           with 0
```

```
else
                        replace coaenesav ;
                           with ( xchp35con ) * xcoacomeff / ;
                        ((( xghp35con ) * xgascomeff ) + ;
                        (( xohp35con ) * xoilcomeff ) + ;
                        (( xchp35con ) * xcoacomeff )) ;
                        * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

********* calculate Lbs. of CFCs displaced ***********

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end
```

```
do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Water

In 1986 in the United States it took about 1,500 gal. of water per day to support one person for food, clothing, and shelter — two to four times what is required in Europe (USGS, September 1992). Daily residential water use in the United States is 77 gal. per capita, compared with 35 gal. in France. Decreasing both the amount of water supplied and the amount of sewage treated yield significant savings to municipalities. Using less water saves money for municipalities in three ways: (1) supplying a lower volume of water means less energy is required for water pumping and wastewater treatment, (2) lower volumes of water reduce the amount of chemicals added for treatment, and (3) municipalities may avoid the construction of new water sources or wastewater treatment facilities. Reduced water consumption also decreases the water and sewer bills for residences, commercial buildings, and factories.

Additionally, reduced water consumption is important because a limited supply of fresh water is available for our consumption. Residential, commercial, industrial, and agricultural activities have been polluting our water reserves. Land disposal of hazardous and radioactive wastes has contaminated groundwater supplies and pesticides and herbicides have contaminated both surface and groundwater supplies. Water diversion projects have drawn toxic metals (e.g., selenium) out of the ground and contaminated the water and the land on which the water has been applied. According to the U.S. Geological Survey, as of 1991, 35 states were pumping groundwater faster than the aquifers were being replenished (USGS, September 1992). Excessive pumping of aquifers has threatened both to drain them, and in coastal areas, to fill them with salt water. Using less water will allow the recharging of aquifers and prevent the migration of contaminants.

Traditionally, water suppliers have considered only supply-side options — ways of providing more water or more wastewater treatment capacity — to provide their customers with more reliable services. As the costs rise to obtain and treat water and wastewater, approaches that use less water more efficiently to deliver unchanged or improved services are proving increasingly cost-effective. Within reason, customers do not care whether they use more or less water as long as they get the desired services with the quality and reliability they want (Rocky Mountain Institute 1991, p 7). On the supply side, this means repairing leaks in the water distribution system. Demand-side

management includes installing, or providing incentives for installing, more efficient plumbing fixtures such as low-flow toilets and showerheads.

REEP analyzes ECOs and WCOs. The WCOs that REEP evaluates include demand-side investments and the resultant water, energy, and pollution savings. One WCO, Water Distribution Leak Repair, looks at supply-side water conservation.

Water Conservation Assumptions

Figure D2 illustrates the average consumption (used in the model) of water per day for a U.S. citizen (Rocky Mountain Institute 1991, p 27). A U.S. family is assumed to have four members. GPD represents the gallons consumed per person per day.

Some bases provide their own water supply and treatment and treat their own sewage as well. Because we have no way of knowing which bases have on-site treatment, the energy savings associated with reduction of water demand are not taken into account. However, the associated cost savings are reflected by the unit costs used in the model.

The Future of Water Conservation

In the future, the energy and cost savings associated with water ECOs can be expected only to increase. Water and wastewater treatment costs will go up as stricter Federal regulations are put into place. As a result, the importance of water conservation will come more clearly into focus and the savings will increase.

Faucet Aerators

Background. Typically, 11 percent of the hot water used in a household passes through the faucets. Faucet aerators reduce the flow a significant amount and save hot water. Faucet aerators should be installed where the force of flow is important, as in washing hands or cleaning dishes. They will not save water where a specific volume of water is required, as in a custodian filling a bucket in a maintenance closet.

Faucet aerators characteristics. A faucet aerator is a low cost ECO that is simple to implement, which is why there is an already large penetration of aerators.

Facility assumptions. This ECO is applied to family housing.

Faucet aerators analysis. The average daily hot water usage for a family is multiplied by the percentage that passes through the faucets to determine the number of gallons of hot water used at faucets. This number is multiplied times the percent reduction in

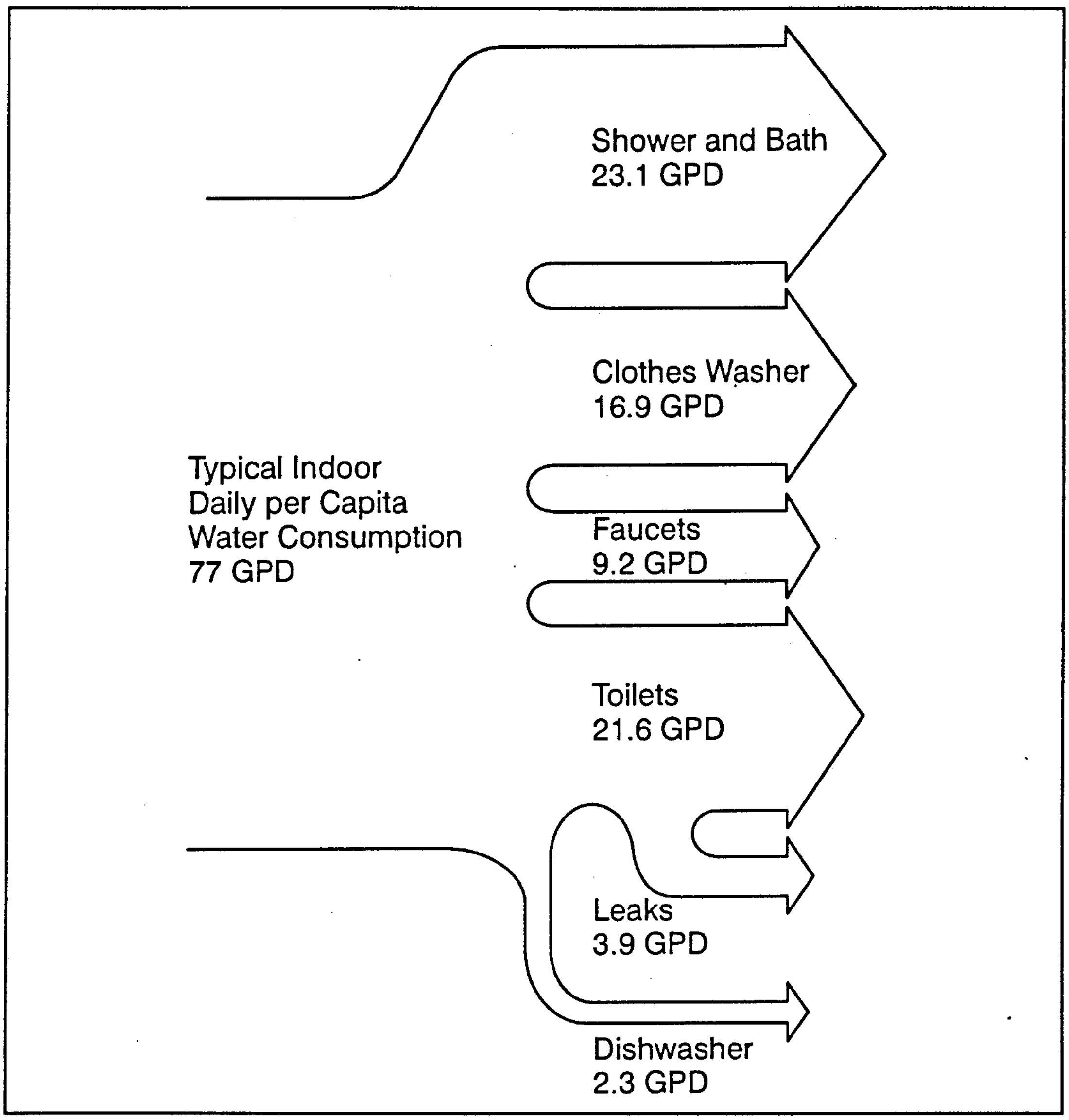


Figure D2. Average water consumption per day for a U.S. citizen.

flow provided by the aerator. This figure is the number of gallons of hot water saved. The energy saved is the energy needed to heat the water. The amount of energy is equal to the delta of the water heater temperature and the ground water temperature multiplied by the number of pounds of water.

Assumptions file.

```
REEP ECO REPORT                                                Page 1
07/20/94

ECO:  Faucet Aerators

FIELD      DESCRIPTION                                          VALUE
----------------------------------------------------------------------
ECO         Energy Opportunity                        Faucet Aerators
```

ECOTYPE	Energy Opportunity Type	Water
PROGRAM	Rules File (Program) Name	faucflow
CAPCOST	Capital Cost	5.00
RECURCOST	Recurring Cost	1.00
ECONLIFE	Economic Life	10.00
DISCQTY	Discount Quantity	1000.00
ASSUM01	ECO Assumption 01	Typ. hot water cons. per day (g
ASSUM01V	ECO Assumption 01 Value	82.00
ASSUM02	ECO Assumption 02	Typ. unit size (ksf)
ASSUM02V	ECO Assumption 02 Value	1.50
ASSUM03	ECO Assumption 03	Aerator savings
ASSUM03V	ECO Assumption 03 Value	50.00
ASSUM04	ECO Assumption 04	Outlet water temp (F)
ASSUM04V	ECO Assumption 04 Value	150.00
ASSUM05	ECO Assumption 05	Faucets per household
ASSUM05V	ECO Assumption 05 Value	3.00
ASSUM06	ECO Assumption 06	% water passes thru faucets
ASSUM06V	ECO Assumption 06 Value	11.00
ASSUM07	ECO Assumption 07	Typ. water cons. per day (gallo
ASSUM07V	ECO Assumption 07 Value	225.00
ASSUM08	ECO Assumption 08	Unit Water Cost Logic Check Val
ASSUM08V	ECO Assumption 08 Value	0.50
ASSUM09	ECO Assumption 09	Electrical Pumping Energy Rate
ASSUM09V	ECO Assumption 09 Value	0.01

Rules file.

```
* This is the faucflow.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xassum02v = 0
      replace numecouni ;
         with 0
else
      replace numecouni ;
         with ( xfamhouare / xassum02v ) *  xassum05v ;
         * ( 1 - penfac )
endif

* numecouni end
```

```
**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

if xassum02v = 0
      replace heaenesav ;
         with 0
else
      replace heaenesav ;
         with ( xfamhouare / xassum02v ) * 365 / 1000000 ;
                  * xassum01v * ( xassum04v - xgrotem ) * ;
                  8.33 * ( xassum06v / 100 ) * ( xassum03v ;
                  / 100 ) * ( 1 - penfac )
endif

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with ( xfamhouare / xassum02v ) * ( xassum03v / 100 ) ;
             * ( xassum06v / 100 ) * xassum07v * 365 / 1000 * ;
             ( 1 - penfac )

* watvolsav end
```

```
********** calculate electric fuel saved **********

* eleenesav start

if xghp75con + xghp75cap = 0
      if xwatseru < xassum08v
            replace eleenesav ;
               with xassum09v * watvolsav + heaenesav ;
                    / .97
      else
            replace eleenesav ;
               with heaenesav / .97
      endif

else
      x = xghp75con + xohp75con + xchp75con
      if x = 0
            if xwatseru < xassum08v
                  replace eleenesav ;
                     with xassum09v * watvolsav
            else
                  replace eleenesav ;
                     with 0
            endif
      else
            if xwatseru < xassum08v
                  replace eleenesav ;
                     with xassum09v * watvolsav + ;
                          heaenesav /.97 * ( 1 - ;
                          ( xghp75con / ( xghp75con + ;
                          xohp75con + xchp75con ) ) )
            else
                  replace eleenesav ;
                     with heaenesav /.97 * ( 1 - ;
                          ( xghp75con / ( xghp75con + ;
                          xohp75con + xchp75con ) ) )
            endif
      endif
endif

* eleenesav end

********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with 0
```

```
* basdemsav end

******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

if xghp75cap + xghp75con > 0
      x = xghp75con + xohp75con + xchp75con
      if x = 0
            replace gasenesav ;
               with 0
      else
            replace gasenesav ;
               with ( heaenesav / .75 ) * xghp75con / ( ;
                    xghp75con + xohp75con + xchp75con )
      endif
else
      replace gasenesav ;
         with 0
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end
```

```
***** Calculate Lbs. of CFCs displaced *****

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav with watvolsav * ( xwatseru + xsewseru )

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Hot Water Heat Pump for Family Housing

Background. Family housing uses a significant amount of the Army's hot water. Hot water heat pumps provide hot water more efficiently than conventional water heaters. Although not included in this analysis, hot water heat pumps can be used to provide spot cooling. During the summer months, the heat pump can circulate heat from the house into the hot water tank. The efficiency of the heat pump is reduced as the source temperature drops.

Hot water heat pump characteristics. This ECO analyzes hot water heat pumps for family housing.

Installed Cost ($):	1,755
Economic Life (years):	20
Recurring Costs (% of initial cost):	0
Heat Pump Wattage (kW):	0.85
Heat Pump COP:	3

Facility assumptions. Existing family housing mechanical systems were assumed to have the following characteristics:

Electric Water Heater Efficiency (%):	97
Gas Water Heater Efficiency (%):	55
Typical family housing size (KSF):	1.5
Average Winter Temperature (°F):	> 45

Hot water heat pump algorithms. The hot water heat pump algorithm bases energy savings on the difference in energy consumption between the old and new units, multiplied by the number of hours the unit would run annually.

Water Heating Load = [Q_{op} (DHWU x 365 days/yr x 8.33 lbm/gallon x (T_T - T_{GW}) / 1,000,000 Btu / MBtu] + Tank Losses

Electric Savings (MBtu/yr) = Q_{op} x (WHL/Eff_{old} - WHL/Eff_{HP})

Gas Savings (MBtu/yr) = Q_{op} x WHL / Eff_{old}

where:

Q_{op} = Number of opportunities

WHL = Annual water heating load

Eff_{old} = Efficiency of old water heater

Tank Losses = (1/R) x A_S x (T_T - T_R) x 24 hrs/day x 365 days/yr

A_S = Surface Area of the Tank

T_T = Tank Temperature

T_R = Room Temperature

T_{GW} = Ground Water Temperature

Hot water heat pump conclusions. Because the hot water heat pump has a moderate installation cost and can only be applied at installations with average winter temperatures above 45 °F, the hot water heat pump could not provide paybacks of less than 10 years at any of the installations. Hot water heat pumps need to be reexamined often as the technology advances.

Assumptions file.

```
REEP ECO REPORT                                              Page 1
09/01/94

ECO:  FH Hot Water Heat Pump

FIELD       DESCRIPTION                                         VALUE
---------------------------------------------------------------------
ECO         Energy Opportunity                 FH Hot Water Heat Pump
UNIT        Unit                                           Heat Pumps
ECOTYPE     Energy Opportunity Type                             Water
PROGRAM     Rules File (Program) Name                        hotwateh
CAPCOST     Capital Cost                                      1755.00
RECURCOST   Recurring Cost                                       0.00
ECONLIFE    Economic Life                                       20.00
DISCQTY     Discount Quantity                                   10.00
ASSUM01     ECO Assumption 01                  FH KSF per water heater
ASSUM01V    ECO Assumption 01 Value                              1.50
ASSUM02     ECO Assumption 02             Efficiency of old water heater
ASSUM02V    ECO Assumption 02 Value                              0.55
ASSUM03     ECO Assumption 03               Water heater size (gallons)
ASSUM03V    ECO Assumption 03 Value                             40.00
ASSUM04     ECO Assumption 04            Daily hot water usage (gallons)
ASSUM04V    ECO Assumption 04 Value                             82.00
ASSUM05     ECO Assumption 05                           Tank temp (F)
ASSUM05V    ECO Assumption 05 Value                            150.00
ASSUM06     ECO Assumption 06                           Heat pump COP
ASSUM06V    ECO Assumption 06 Value                              3.00
ASSUM07     ECO Assumption 07                  Heat pump wattage (kW)
ASSUM07V    ECO Assumption 07 Value                              0.85
```

Rules file.

```
* This is the hotwateh.prg program

* SECTION 1 - ECO specific calculations
```

```
********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xassum01v = 0
      replace numecouni ;
         with 0
else
      if 65 - xhdd / xheaseaday > 40
            replace numecouni ;
               with xfamhouare / xassum01v * ( 1 - penfac )
      else
            replace numecouni ;
               with 0
      endif
endif

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

if xassum05v = xgrotem
      replace heaenesav ;
         with 0
else
      replace heaenesav ;
```

```
          with numecouni * xassum04v * 365 * 8.33 * ;
                ( xassum05v - xgrotem ) / 1000000
endif

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

*********** calculate electric fuel saved **********

* eleenesav start

if ( xghp75con + xohp75con + xchp75con ) = 0
      replace eleenesav with 0
else
      if xghp75con + xghp75cap = 0
            replace eleenesav ;
               with heaenesav / .97 - heaenesav / xassum06v
      else
            replace eleenesav ;
               with ( .( heaenesav / .97 - heaenesav / xassum06v ;
                  ) * ( 1 - ( xghp75con / ( xghp75con + ;
                  xohp75con + xchp75con ) ) ) - heaenesav / ;
                  xassum06v )
      endif
endif

* eleenesav end

********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end
```

```
******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

if xghp75cap + xghp75con > 0
      x = xghp75con + xohp75con + xchp75con
      if x = 0
            replace gasenesav ;
               with 0
      else
            replace gasenesav ;
               with ( heaenesav / xassum02v ) * xghp75con / ;
                     ( xghp75con + xohp75con + xchp75con )
      endif
else
      replace gasenesav ;
         with 0
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0
```

```
* coaenesav end

********** calculate water volume saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

**** Calculate Lbs. of CFCs displaced *****

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved ***********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Tankless Water Heaters for Family Housing

Background. Family housing uses a significant amount of the Army's hot water. Almost one quarter of the energy used for water heating is used to offset the losses from the hot water tank. By reducing the size or completely eliminating the tank, tankless water heaters save the energy normally lost through the tank.

Tankless water heater characteristics. This ECO analyzes the replacement of conventional water heaters with tankless water heaters in training, administration, community, and family housing facilities. The tankless water heater completely replaces the existing water heater and can provide hot water at a fairly constant output temperature until the output of the unit is exceeded. The temperature of the water will drop as the flow rate is increased. Tankless water heaters are not recommended for retrofits requiring high flow rates.

Facility assumptions. This ECO assumes there is one water heater in every house and there is a water heater for every 6,000 sq ft of the other facilities.

Tankless water heater algorithms. The tankless water heater algorithm bases energy savings on the elimination of the tank losses or standby losses. These losses were calculated using the assumption for tank temperature, tank insulation, and room temperature.

Assumptions file.

```
REEP ECO REPORT                                                Page 1
07/20/94

ECO:  FH Tankless Water Heaters

FIELD       DESCRIPTION                                         VALUE
---------------------------------------------------------------------
ECO         Energy Opportunity               FH Tankless Water Heaters
UNIT        Unit                                               Heaters
ECOTYPE     Energy Opportunity Type                              Water
PROGRAM     Rules File (Program) Name                         insthotw
CAPCOST     Capital Cost                                        625.00
RECURCOST   Recurring Cost                                        0.00
ECONLIFE    Economic Life                                        10.00
DISCQTY     Discount Quantity                                    10.00
ASSUM01     ECO Assumption 01          ECO density other than FH (ksf)
ASSUM01V    ECO Assumption 01 Value                               6.00
ASSUM02     ECO Assumption 02                 ECO density for FH (ksf)
ASSUM02V    ECO Assumption 02 Value                               1.50
```

ASSUM03	ECO Assumption 03	% of floor area affected
ASSUM03V	ECO Assumption 03 Value	1.00
ASSUM04	ECO Assumption 04	Annual hours of operation
ASSUM04V	ECO Assumption 04 Value	8760.00
ASSUM05	ECO Assumption 05	HVAC cooling energy credit
ASSUM05V	ECO Assumption 05 Value	0.00
ASSUM06	ECO Assumption 06	HVAC cooling demand savings
ASSUM06V	ECO Assumption 06 Value	0.00
ASSUM07	ECO Assumption 07	Efficiency of gas WH
ASSUM07V	ECO Assumption 07 Value	0.55
ASSUM08	ECO Assumption 08	Efficiency of electric WH
ASSUM08V	ECO Assumption 08 Value	0.97
ASSUM09	ECO Assumption 09	Tank temp (F)
ASSUM09V	ECO Assumption 09 Value	150.00
ASSUM10	ECO Assumption 10	Tank capacity (gallons)
ASSUM10V	ECO Assumption 10 Value	40.00
ASSUM11	ECO Assumption 11	Tank R-value
ASSUM11V	ECO Assumption 11 Value	6.00
ASSUM12	ECO Assumption 12	Room temp (F)
ASSUM12V	ECO Assumption 12 Value	70.00
ASSUM13	ECO Assumption 13	Surface area (SF)
ASSUM13V	ECO Assumption 13 Value	25.13

Rules file.

```
* This is the insthotw.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xassum02v + xassum01v = 0
      replace numecouni ;
         with 0
else
      replace numecouni ;
         with ( ( ( xtraare + xadmare + xcomfacare ) / ;
              xassum01v ) + ( xfamhouare / xassum02v ) ) ;
              * ( 1 - penfac )
endif
```

```
* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * ( ( 1 / xassum11v ) * xassum13v * ( ;
        xassum09v - xassum12v ) * xassum04v / 1000000 )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

if xghp75con + xghp75cap = 0
      replace eleenesav ;
         with heaenesav / xassum08v
else
      x = xghp75con + xohp75con + xchp75con
      if x = 0
```

```
            replace eleenesav ;
               with 0
      else
            replace eleenesav ;
               with heaenesav / xassum08v * ( 1 - ( ;
                    xghp75con / ( xghp75con + xohp75con + ;
                    xchp75con ) ) )
      endif
endif

* eleenesav end

********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
     with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

if xghp75cap + xghp75con > 0
      x = xghp75con + xohp75con + xchp75con
      if x = 0
            replace gasenesav ;
               with 0
      else
            replace gasenesav ;
               with ( heaenesav / xassum07v ) * xghp75con / ;
                    ( xghp75con + xohp75con + xchp75con )
      endif
else
```

```
      replace gasenesav ;
         with 0
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water volume saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

***** Calculate Lbs. of CFCs displaced *****

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1
```

```
********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Ultra Low Flow Toilets for Family Housing

Background. Typically, 28 percent of the water used in a household is used by the toilet and 5 percent is lost through leaks in the toilet. Ultra low flow toilets can greatly reduce the amount of water necessary for operation of the toilet. The reduced amount of water used by ultra low flow toilets will reduce the velocity of wastewater flow. Therefore, for new installations, downsized collection systems should be incorporated with the installation of the ultra low flow toilets. The installed cost is for two toilets and was taken from "Means Repair & Remodeling Cost Data-1993" (Chandler 1992). These algorithms are based on information provided by American Standard. American Standard cites USEPA Study 600/2-80-137, "Effects of Water Conservation Induced Waste Water Flow Reduction" to conclude that a 100 percent conversion to ultra low flow toilets will not affect sewer operation or maintenance adversely.

Facility assumptions. This analysis covers only family housing. There are assumed to be four residents per household. The number of flushes per day is assumed to be four per person for a total of 16 per day for a household.

Average Daily Usage:	16	Flushes/day-hsehld (four flushes/day-person × four people)
Existing Toilet flush (gal.):	6	(typical toilet 5 to 7 gal)

Ultra Low Flow Gallons per flush (gal):	1.6	
Gallons saved per flush (gal):	4.4	(6 to 1.6 gal)

Assumptions file.

```
REEP ECO REPORT                                                 Page 1
07/20/94

ECO:  FH Ultra Low Flow Toilets

FIELD       DESCRIPTION                                          VALUE
----------------------------------------------------------------------
ECO          Energy Opportunity                FH Ultra Low Flow Toilets
UNIT         Unit                                               Toilets
ECOTYPE      Energy Opportunity Type                              Water
PROGRAM      Rules File (Program) Name                         ultloflo
CAPCOST      Capital Cost                                        670.00
RECURCOST    Recurring Cost                                        0.00
ECONLIFE     Economic Life                                        20.00
DISCQTY      Discount Quantity                                    20.00
ASSUM01      ECO Assumption 01                  Gallons saved per flush
ASSUM01V     ECO Assumption 01 Value                               4.40
ASSUM02      ECO Assumption 02                        Building size KSF
ASSUM02V     ECO Assumption 02 Value                               1.50
ASSUM03      ECO Assumption 03            Flushes per day per household
ASSUM03V     ECO Assumption 03 Value                              16.00
ASSUM04      ECO Assumption 04                Existing gallons per flush
ASSUM04V     ECO Assumption 04 Value                               6.00
ASSUM05      ECO Assumption 05                      Toilets per household
ASSUM05V     ECO Assumption 05 Value                               2.00
ASSUM06      ECO Assumption 06           Unit Water Cost Logic Check Val
ASSUM06V     ECO Assumption 06 Value                               0.50
ASSUM07      ECO Assumption 07             Electrical Pumping Energy Rate
ASSUM07V     ECO Assumption 07 Value                               0.01
```

Rules file.

```
* This is the ultloflo.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start
```

```
if xassum02v = 0
      replace numecouni ;
         with 0
else
      replace numecouni ;
         with ( xfamhouare / xassum02v ) * ;
                xassum05v * ( 1 - penfac )
endif

* numecouni end

********** Select Project Size Factor **********

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
         with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with numecouni * xassum01v * xassum03v * 365 / 1000
```

```
* watvolsav end

********** calculate electric fuel saved **********

* eleenesav start

if xwatseru < xassum06v
  replace eleenesav ;
     with xassum07v * watvolsav
else
  replace eleenesav ;
     with 0
endif

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) * xgascomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xgascomeff / 100 )
```

```
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) * xoilcomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) * xcoacomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate Lbs. of CFCs displaced **********

* cfcdisp start

replace cfcdisp ;
  with 0
```

```
* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with watvolsav * (xwatseru + xsewseru )

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Flush Valve Retrofits

Background. Sloan Royal and Regal Flush valves can be retrofitted with water saving devices that shorten the flush cycle of the valves without restricting the water flow. This allows the pressure necessary for effective cleansing using less water. Water saving devices installed in these flush valves have been found to save up to 50 percent of the water used by these fixtures. Because of the variation in valve models, ages, and conditions, expectations are that 30 to 40 percent of water can be saved. Installation should take a few minutes per valve and requires no special tools. It requires only the unscrewing of the outer cover, the removal of the inner core, the placement of the device over the plastic relief valve, and the replacement of the removed covers. These devices are not designed for use on newer, low consumption urinal or water closet flush valves and a penetration factor is used to account for the newer models.

Labor cost information is taken from "Means Residential Cost Data-1993," and the unit cost from the General Services Administration (GSA) Catalog (FSC Class 4510, Contract number GS-07F-5618A). Economic life was taken from information provided by Trademark Sales and Marketing, Neenah, Wisconsin.

Flush valve retrofit characteristics.

Installed Cost: $6.50 ($4.50 per unit + [$16 per hr/8 retrofits per hr])

Facility assumptions.

Square feet per person:	Values taken from 1987 BOCA National Building Code
No. of people per fixture:	Values taken from 1983 National Standard Plumbing Code
Average Daily Usage:	Estimated
Existing Valve flush (gal.):	5
Percent of Water Saved (%):	40
Gallons saved per flush:	2.0

Assumptions file.

REEP ECO REPORT Page 1
07/20/94

ECO: Flush Valve Retrofits

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	Flush Valve Retrofits
UNIT	Unit	Valves
ECOTYPE	Energy Opportunity Type	Water
PROGRAM	Rules File (Program) Name	flushval
CAPCOST	Capital Cost	6.50
RECURCOST	Recurring Cost	0.00
ECONLIFE	Economic Life	10.00
DISCQTY	Discount Quantity	200.00
ASSUM01	ECO Assumption 01	ksf/person-training
ASSUM01V	ECO Assumption 01 Value	0.05
ASSUM02	ECO Assumption 02	ksf/person-r, d, & t / administ
ASSUM02V	ECO Assumption 02 Value	0.10
ASSUM03	ECO Assumption 03	ksf/person-hospital/medical
ASSUM03V	ECO Assumption 03 Value	0.20
ASSUM04	ECO Assumption 04	Unit Water Cost Logic Check Val
ASSUM04V	ECO Assumption 04 Value	0.50
ASSUM05	ECO Assumption 05	ksf/person-barracks
ASSUM05V	ECO Assumption 05 Value	0.20
ASSUM06	ECO Assumption 06	ksf/person-community facilities
ASSUM06V	ECO Assumption 06 Value	0.10
ASSUM07	ECO Assumption 07	persons/fixture-training
ASSUM07V	ECO Assumption 07 Value	30.00
ASSUM08	ECO Assumption 08	persons/fixture-research, devel
ASSUM08V	ECO Assumption 08 Value	25.00
ASSUM09	ECO Assumption 09	persons/fixture-hospital/medica
ASSUM09V	ECO Assumption 09 Value	8.00

ASSUM10	ECO Assumption 10	persons/fixture-administrative
ASSUM10V	ECO Assumption 10 Value	25.00
ASSUM11	ECO Assumption 11	persons/fixture-barracks
ASSUM11V	ECO Assumption 11 Value	20.00
ASSUM12	ECO Assumption 12	persons/fixture-community facil
ASSUM12V	ECO Assumption 12 Value	25.00
ASSUM13	ECO Assumption 13	flushes/day/person-training
ASSUM13V	ECO Assumption 13 Value	2.00
ASSUM14	ECO Assumption 14	flushes/day/person-research, de
ASSUM14V	ECO Assumption 14 Value	2.00
ASSUM15	ECO Assumption 15	flushes/day/person-hospital/med
ASSUM15V	ECO Assumption 15 Value	2.00
ASSUM16	ECO Assumption 16	flushes/day/person-administrati
ASSUM16V	ECO Assumption 16 Value	2.00
ASSUM17	ECO Assumption 17	flushes/day/person-barracks
ASSUM17V	ECO Assumption 17 Value	4.00
ASSUM18	ECO Assumption 18	flushes/day/person-community fa
ASSUM18V	ECO Assumption 18 Value	1.00
ASSUM19	ECO Assumption 19	gallons saved per flush
ASSUM19V	ECO Assumption 19 Value	2.00
ASSUM20	ECO Assumption 20	Electrical Pumping Energy Rate
ASSUM20V	ECO Assumption 20 Value	0.01

Rules file.

```
* This is the flushval.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with              ( ( ( xtraare / xassum01v ) / xassum07v ) + ;
                     ( ( xrdtare / xassum02v ) / xassum08v ) + ;
                     ( ( xhosmedare / xassum03v ) / xassum09v ) + ;
                     ( ( xadmare / xassum02v ) / xassum10v ) + ;
                     ( ( xbarare / xassum05v ) / xassum11v ) + ;
                     ( ( xcomfacare / xassum06v ) / xassum12v ) ) ;
                     * ( 1 - penfac )

* numecouni end
```

```
**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
   with xcapcost * xlocind * numecouni * prosizfac

* inicos end

********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

******** calculate summer demand fuel saved *******

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end
```

```
********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with                 ( ( ( xtraare / xassum01v ) * xassum13v ) + ;
                        ( ( xrdtare / xassum02v ) * xassum14v ) + ;
                        ( ( xhosmedare / xassum03v ) * xassum15v ) + ;
                        ( ( xadmare / xassum02v ) * xassum16v ) + ;
                        ( ( xbarare / xassum05v ) * xassum17v ) + ;
                        ( ( xcomfacare / xassum06v ) * xassum18v ) ) ;
                        * ( xassum19v ) * ( 1 - penfac ) / 1000

* watvolsav end

********** calculate electric fuel saved **********

* eleenesav start

if xwatseru < xassum04v
  replace eleenesav ;
     with xassum20v * watvolsav
else
  replace eleenesav ;
     with 0
endif

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved *********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********
```

```
* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

***** Calculate Lbs. of CFCs displaced *****

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations

do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with watvolsav * ( xwatseru + xsewseru )

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Horizontal Axis Washing Machines

Background. Typically, 22 percent of the water used in a household is used by the clothes washing machine. Front-loading washing machines use considerably less water than the conventional top-loading washers. They use less energy and detergent while

spin drying clothes more thoroughly and therefore reduce the energy necessary to dry clothes in the clothes dryer. The algorithms are based on information provided by White-Westinghouse. The one model available on the North American market is under the Sears Kenmore, White-Westinghouse, and Gibson labels.

Facility assumptions. This analysis covers only family housing. There are assumed to be four residents per household. The number of washes per day is assumed to be one for a family of four.

Existing gallons per wash:	43.5
Horizontal Axis gallons per wash:	28
Gallons saved per wash:	15.5

Assumptions file.

```
REEP ECO REPORT                                               Page 1
07/20/94

ECO:  Horizntl Axis Washng Mchns

FIELD      DESCRIPTION                                         VALUE
--------------------------------------------------------------------
ECO         Energy Opportunity              Horizntl Axis Washng Mchns
UNIT        Unit                                              Machines
ECOTYPE     Energy Opportunity Type                              Water
PROGRAM     Rules File (Program) Name                         horiwash
CAPCOST     Capital Cost                                        700.00
RECURCOST   Recurring Cost                                        0.00
ECONLIFE    Economic Life                                        15.00
DISCQTY     Discount Quantity                                    20.00
ASSUM01     ECO Assumption 01                   Gallons saved per wash
ASSUM01V    ECO Assumption 01 Value                              15.50
ASSUM02     ECO Assumption 02                        Building size KSF
ASSUM02V    ECO Assumption 02 Value                               1.50
ASSUM03     ECO Assumption 03                       Washes/day-house
ASSUM03V    ECO Assumption 03 Value                               1.00
ASSUM04     ECO Assumption 04                 Number of washers/house
ASSUM04V    ECO Assumption 04 Value                               1.00
ASSUM05     ECO Assumption 05             Hot water used in horizontal wa
ASSUM05V    ECO Assumption 05 Value                              50.00
ASSUM06     ECO Assumption 06                         Tank temperature
ASSUM06V    ECO Assumption 06 Value                             150.00
ASSUM07     ECO Assumption 07             Unit Water Cost Logic Check Val
ASSUM07V    ECO Assumption 07 Value                               0.50
ASSUM08     ECO Assumption 08               Electrical Pumping Energy Rate
ASSUM08V    ECO Assumption 08 Value                               0.01
```

Rules file.

```
* This is the horiwash.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xassum02v = 0
      replace numecouni ;
         with 0
else
      replace numecouni ;
         with ( xfamhouare / xassum02v ) * xassum04v ;
         * ( 1 - penfac )
endif

* numecouni end

********** Select Project Size Factor ************

do comcalc0

********** calculate adjusted initial cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * xassum01v * xassum03v * 365  * ;
             ( xassum05v / 100 ) * ( xassum06v - xgrotem ) ;
             * 8.33 / 1000000

* heaenesav end
```

```
********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with numecouni * xassum01v * xassum03v * 365 ;
         / 1000

* watvolsav end

********** calculate electric fuel saved **********

* eleenesav start

if xghp75con + xghp75cap = 0
      if xwatseru < xassum07v
            replace eleenesav ;
               with xassum08v * watvolsav + heaenesav ;
                    / .97
      else
            replace eleenesav ;
               with heaenesav / .97
      endif

else
      x = xghp75con + xohp75con + xchp75con
      if x = 0
            if xwatseru < xassum07v
                  replace eleenesav ;
                     with xassum08v * watvolsav
            else
                  replace eleenesav ;
                     with 0
            endif
      else
            if xwatseru < xassum07v
                  replace eleenesav ;
                     with xassum08v * watvolsav + ;
                          heaenesav /.97 * ( 1.- ;
                          ( xghp75con / ( xghp75con + ;
```

```
                        xohp75con + xchp75con ) ) )
            else
                  replace eleenesav ;
                     with heaenesav /.97 * ( 1 - ;
                        ( xghp75con / ( xghp75con + ;
                        xohp75con + xchp75con ) ) )
            endif
      endif
endif

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) * xgascomeff / ;
        ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
         (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
         (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
         * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end
```

```
********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) * xoilcomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) * xcoacomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate Lbs. of CFCs displaced **********

* cfcdisp start

replace cfcdisp ;
  with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1
```

```
********** calculate water cost saved **********

* watcossav start

replace watcossav with watvolsav * ( xwatseru + xsewseru )

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Water Saving Shower Head

Background. Many older style shower heads provide a heavy stream of water that results in much wasted water during a shower. Water saving shower heads provide superior spray patterns at much lower flow rates, which saves water and energy. Typically, 50 percent of the hot water used in a household passes through the shower head. Reducing the amount of hot water consumed saves the energy needed to heat the water.

Water saving shower head characteristics. A water saving shower head is a low cost ECO that is easy to retrofit. For this reason there is a relatively high penetration of water saving shower heads on military installations.

Facility assumptions. This ECO only looks at family housing and assumes only one shower head per house.

Water saving shower head analysis. The percentage of the total household hot water that passes through the shower head is based on information from Bancroft (1991). This percentage is used to determine the number of gallons that flow through the shower head. The water saving percentage provided by the shower head is multiplied by the number of gallons of hot water passing through the shower head. The results are the number of gallons of hot water saved. The energy used to heat the water is calculated using the local ground water temperature.

Assumptions file.

```
REEP ECO REPORT                                                     Page 1
07/20/94

ECO:  Low-flow Shower Head
FIELD      DESCRIPTION                                              VALUE
---------------------------------------------------------------------------
ECO         Energy Opportunity                          Low-flow Shower Head
UNIT        Unit                                                 Shwr Heads
ECOTYPE     Energy Opportunity Type                                   Water
PROGRAM     Rules File (Program) Name                              showflow
CAPCOST     Capital Cost                                              20.00
RECURCOST   Recurring Cost                                             0.00
ECONLIFE    Economic Life                                             10.00
DISCQTY     Discount Quantity                                       1000.00
ASSUM01     ECO Assumption 01            Typ. hot water cons. per day (g
ASSUM01V    ECO Assumption 01 Value                                   70.00
ASSUM02     ECO Assumption 02                          Typ. unit size (ksf)
ASSUM02V    ECO Assumption 02 Value                                    1.50
ASSUM03     ECO Assumption 03                Showerhead water savings (%)
ASSUM03V    ECO Assumption 03 Value                                   40.00
ASSUM04     ECO Assumption 04                       Outlet water temp (F)
ASSUM04V    ECO Assumption 04 Value                                  150.00
ASSUM05     ECO Assumption 05                       Shower heads per unit
ASSUM05V    ECO Assumption 05 Value                                    1.00
ASSUM06     ECO Assumption 06              % hot water thru shower heads
ASSUM06V    ECO Assumption 06 Value                                   50.00
ASSUM07     ECO Assumption 07            Typ. water cons. per day in sho
ASSUM07V    ECO Assumption 07 Value                                   82.00
ASSUM08     ECO Assumption 08            Unit Water Cost Logic Check Val
ASSUM08V    ECO Assumption 08 Value                                    0.50
ASSUM09     ECO Assumption 09              Electrical Pumping Energy Rate
ASSUM09V    ECO Assumption 09 Value                                    0.01
```

Rules file.

```
* This is the showflow.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

if xassum02v = 0
      replace numecouni ;
```

```
          with 0
else
      replace numecouni ;
          with ( xfamhouare / xassum02v ) *  xassum05v ;
          * ( 1 - penfac )
endif

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

if xassum05v = 0
      replace heaenesav ;
         with 0
else
      replace heaenesav ;
         with numecouni * 365 / 1000000 * xassum01v * ;
                  ( xassum04v - xgrotem ) * 8.33 * ;
              ( xassum06v / 100 ) * ( xassum03v / 100 )
endif

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate water saved **********

* watvolsav start
```

```
replace watvolsav ;
   with ( xfamhouare / xassum02v ) * ( xassum03v / 100 ) ;
            * xassum07v * 365 / 1000 * ( 1 - penfac )

* watvolsav end

********** calculate electric fuel saved **********

* eleenesav start

if xghp75con + xghp75cap = 0
      if xwatseru < xassum08v
            replace eleenesav ;
               with xassum09v * watvolsav + heaenesav ;
                    / .97
      else
            replace eleenesav ;
               with heaenesav / .97
      endif

else
      x = xghp75con + xohp75con + xchp75con
      if x = 0
            if xwatseru < xassum08v
                  replace eleenesav ;
                     with xassum09v * watvolsav
            else
                  replace eleenesav ;
                     with 0
            endif
      else
            if xwatseru < xassum08v
                  replace eleenesav ;
                     with xassum09v * watvolsav + ;
                          heaenesav /.97 * ( 1 - ;
                          ( xghp75con / ( xghp75con + ;
                          xohp75con + xchp75con ) ) )
            else
                  replace eleenesav ;
                     with heaenesav /.97 * ( 1 - ;
                          ( xghp75con / ( xghp75con + ;
                          xohp75con + xchp75con ) ) )
            endif
      endif
endif

* eleenesav end

********** calculate base load fuel saved **********

* basdemsav start
```

```
replace basdemsav ;
   with 0

* basdemsav end

******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
     with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

if xghp75cap + xghp75con > 0
      x = xghp75con + xohp75con + xchp75con
      if x = 0
            replace gasenesav ;
               with 0
      else
            replace gasenesav ;
               with ( heaenesav / .75 ) * xghp75con / ( ;
                    xghp75con + xohp75con + xchp75con )
      endif
else
      replace gasenesav ;
         with 0
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0
```

```
* coaenesav end

***** Calculate Lbs. of CFCs displaced *****

* cfcdisp start

replace cfcdisp ;
   with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav with watvolsav * ( xwatseru + xsewseru )

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Water Conserving Dishwashers

Background. Typically, 3 percent of the water used in a household is used for dish washing. This usage averages about 9.2 gal. per day for a household of four. Water conserving dishwashers are now available that use around half the water used by a traditional automatic dishwasher. The water consumption data used in this ECO are based on information provided by Whirlpool Corporation. This ECO was applied only to family housing. The installed cost was taken from "Means Residential Cost Data 1993."

Facility assumptions. This analysis covers only family housing. The average household is assumed to have four residents. The number of washes per day is calculated from the

average water usage per day of 9.2 gallons (2.3 gal/day-person × 4 people) divided by an existing dishwasher water consumption of 12.5 gal./wash.

Assumptions file.

```
REEP ECO REPORT                                               Page 1
07/20/94

ECO:  Water Consrvng Dishwshrs

FIELD       DESCRIPTION                                        VALUE
--------------------------------------------------------------------
ECO         Energy Opportunity              Water Consrvng Dishwshrs
UNIT        Unit                                           Dishwshrs
ECOTYPE     Energy Opportunity Type                            Water
PROGRAM     Rules File (Program) Name                       dishwash
CAPCOST     Capital Cost                                      410.00
RECURCOST   Recurring Cost                                      0.00
ECONLIFE    Economic Life                                      10.00
DISCQTY     Discount Quantity                                  10.00
ASSUM01     ECO Assumption 01                      Building Size KSF
ASSUM01V    ECO Assumption 01 Value                             1.50
ASSUM02     ECO Assumption 02                          Washes per day
ASSUM02V    ECO Assumption 02 Value                             0.74
ASSUM03     ECO Assumption 03         New Dishwasher consumption (gal
ASSUM03V    ECO Assumption 03 Value                             5.30
ASSUM04     ECO Assumption 04         Old Dishwasher consumption (gal
ASSUM04V    ECO Assumption 04 Value                            12.50
ASSUM05     ECO Assumption 05          Number of washers/building (F
ASSUM05V    ECO Assumption 05 Value                             1.00
ASSUM06     ECO Assumption 06                       Tank Temperature
ASSUM06V    ECO Assumption 06 Value                           150.00
ASSUM07     ECO Assumption 07         Unit Water Cost Logic Check Val
ASSUM07V    ECO Assumption 07 Value                             0.50
ASSUM08     ECO Assumption 08           Electrical Pumping Energy Rate
ASSUM08V    ECO Assumption 08 Value                             0.01
```

Rules file.

```
* This is the dishwash.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********
```

```
* numecouni start

if xassum01v = 0
      replace numecouni ;
         with 0
else
      replace numecouni ;
         with xfamhouare / xassum01v * ( 1 - penfac )
endif

* numecouni end

********** Select Project Size Factor **********

do comcalc0

********** calculate initial cost **********

* inicos start

replace inicos ;
   with numecouni * xcapcost * xlocind * prosizfac

* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * xassum02v * xassum05v * 365 ;
            * ( xassum04v - xassum03v ) / 1000000 ;
            * 8.33 * ( xassum06v - xgrotem )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start
```

```
if xghp75con + xghp75cap = 0
      if xwatseru < xassum07v
            replace eleenesav ;
               with xassum08v * watvolsav + heaenesav ;
                    / .97
      else
            replace eleenesav ;
               with heaenesav / .97
      endif

else
      x = xghp75con + xohp75con + xchp75con
      if x = 0
            if xwatseru < xassum07v
                  replace eleenesav ;
                     with xassum08v * watvolsav
            else
                  replace eleenesav ;
                     with 0
            endif
      else
            if xwatseru < xassum07v
                  replace eleenesav ;
                     with xassum08v * watvolsav + ;
                          heaenesav /.97 * ( 1 - ;
                          ( xghp75con / ( xghp75con + ;
                          xohp75con + xchp75con ) ) )
            else
                  replace eleenesav ;
                     with heaenesav /.97 * ( 1 - ;
                          ( xghp75con / ( xghp75con + ;
                          xohp75con + xchp75con ) ) )
            endif
      endif
endif

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********
```

```
* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

zcheck = xghp35con + xghp7535con + xghp75con
if zcheck = 0
  replace gasenesav ;
     with 0
else
  replace gasenesav ;
     with ( xghp35con + xghp7535con + xghp75con ) * xgascomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xgascomeff / 100 )
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

zcheck = xohp35con + xohp7535con + xohp75con
if zcheck = 0
  replace oilenesav ;
     with 0
else
  replace oilenesav ;
     with ( xohp35con + xohp7535con + xohp75con ) * xoilcomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xoilcomeff / 100 )
endif

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start
```

```
zcheck = xchp35con + xchp7535con + xchp75con
if zcheck = 0
  replace coaenesav ;
     with 0
else
  replace coaenesav ;
     with ( xchp35con + xchp7535con + xchp75con ) * xcoacomeff / ;
         ((( xghp35con + xghp7535con + xghp75con ) * xgascomeff ) + ;
          (( xohp35con + xohp7535con + xohp75con ) * xoilcomeff ) + ;
          (( xchp35con + xchp7535con + xchp75con ) * xcoacomeff )) ;
          * heaenesav / ( xcoacomeff / 100 )
endif

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with numecouni * xassum02v * xassum05v * 365 ;
            * ( xassum04v - xassum03v ) / 1000

* watvolsav end

********** calculate Lbs. of CFCs displaced **********

* cfcdisp start

replace cfcdisp ;
  with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with watvolsav * ( xwatseru + xsewseru )

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start
```

```
replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Water Distribution Leak Repair

Background. Currently, most military installations do not meter the flow of water through their potable water system for each residence and facility. Military personnel pay a base rent for an unlimited supply. As a result, no direct way exists to monitor the amount of water consumed, wasted, or lost in transit. A comprehensive leak detection and repair program might lead to substantial economic savings for repair of leaks found in distribution system mains (Maloney, Scholze, and Bandy, March 1986). The cost-effectiveness of such a leak detection program depends on several factors—an important one is the water treatment/purchase cost. This ECO was applied military-wide based on each installation's length of potable water distribution system and water treatment and purchase cost. No sewage treatment savings are associated with this ECO because it is strictly a supply-side measure and does not reduce the end user's consumption.

The amount of water lost by various installation's potable water distribution systems has been found to be between 9 and 36 percent in previous studies (Maloney, Scholze, and Bandy, March 1986). This ECO assumes that 18 percent of the water at a typical installation is lost in transit and that the implementation of a leak repair program can reduce that percentage by 50 percent.

Water distribution leak repair characteristics.

Cost of Survey ($/mile):	500	
Cost of Repair ($/leak):	750	
Total Installed Cost ($/mile):	1063	500 + 750 (0.75)

Facility assumptions.

No. of Leaks per mile:	0.75

Assumptions file.

```
REEP ECO REPORT                                          Page 1
07/20/94
```

ECO: Water Distibtn Leak Repair

FIELD	DESCRIPTION	VALUE
ECO	Energy Opportunity	Water Distibtn Leak Repair
UNIT	Unit	Repairs
ECOTYPE	Energy Opportunity Type	Water
PROGRAM	Rules File (Program) Name	distleak
CAPCOST	Capital Cost	1063.00
RECURCOST	Recurring Cost	0.00
ECONLIFE	Economic Life	20.00
DISCQTY	Discount Quantity	30.00
ASSUM01	ECO Assumption 01	Percent of Water Lost due to ex
ASSUM01V	ECO Assumption 01 Value	18.00
ASSUM02	ECO Assumption 02	Percent reduction of leaks due
ASSUM02V	ECO Assumption 02 Value	50.00
ASSUM03	ECO Assumption 03	Unit Water Cost Logic Check Val
ASSUM03V	ECO Assumption 03 Value	0.50
ASSUM04	ECO Assumption 04	Electrical Pumping Energy Rate
ASSUM04V	ECO Assumption 04 Value	0.01

Rules file.

```
* This is the distleak.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with xwatdis / 5.280 * ( 1 - penfac )

* numecouni end

********** select project size factor ***********

do comcalc0

********** calculate adjusted initial cost **********

* inicos start

replace inicos ;
   with xcapcost * numecouni * prosizfac
```

```
* inicos end

********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with 0

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with xwatserq * ( xassum01v / 100 ) * ;
     ( xassum02v / 100 ) * ( 1 - penfac )

* watvolsav end

********** calculate electric fuel saved **********

* eleenesav start

if xwatseru < xassum03v
  replace eleenesav ;
     with xassum04v * watvolsav
else
  replace eleenesav ;
     with 0
endif

* eleenesav end

********** calculate baseload demand saved **********

* basdemsav start
```

```
replace basdemsav ;
   with 0

* basdemsav end

********** calculate summer demand saved **********

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end

********** calculate gas fuel saved **********

* gasenesav start

replace gasenesav ;
   with 0

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate Lbs. of CFCs displaced **********

* cfcdisp start

replace cfcdisp ;
  with 0

* cfcdisp end
```

```
* SECTION 2 - Common calculations and HVAC calculations
do comcalc1

********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with watvolsav * xwatseru

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Water Heater Insulation Blanket

Background. From the day a water heater is brought on-line until the day it is decommissioned, it dissipates heat to its ambient environment. These losses can represent 25 percent of the energy consumed by a water heater. This particular ECO evaluates the effectiveness of installing an insulating jacket around the water heater to reduce the energy lost to the environment.

Insulation Blanket Characteristics		
Tank insulation R-value:	6	
Insulation jacket R-value:	5	
Installed cost of insulation jacket ($):	20	(Kiley and Moselle 1990)
Recurring cost (% of CC):	0	
Economic Life (years):	10	
Water Temperature (°F):	150	
Ambient Temperature (°F):	70	
Effective Surface area (sq ft):	25.13	

Facility assumptions. To estimate the quantity of water heaters per particular facility types, the following water heater densities were used:

One 40-gal. water heater every:

Family Housing (KSF):	1.5	
Administration (KSF):	6.0	
Community (KSF):	6.0	
Training (KSF):	6.0	
Annual Hours of Operation	8,760	(24 hr/day x 365 days/yr)

Insulation blanket conclusions. Tank insulation jackets have simple paybacks ranging from under 1 year to over 2 years. This range is due to variations in energy costs.

Assumptions file.

```
REEP ECO REPORT                                              Page 1
09/01/94

ECO:  Wtr Htr Insulation Blanket

FIELD        DESCRIPTION                                      VALUE
-------------------------------------------------------------------
ECO          Energy Opportunity           Wtr Htr Insulation Blanket
UNIT         Unit                                           Blankets
ECOTYPE      Energy Opportunity Type                           Water
PROGRAM      Rules File (Program) Name                      wateblan
CAPCOST      Capital Cost                                      20.00
RECURCOST    Recurring Cost                                     0.00
ECONLIFE     Economic Life                                     10.00
DISCQTY      Discount Quantity                                200.00
ASSUM01      ECO Assumption 01       ECO density for fac. not FH (ks
ASSUM01V     ECO Assumption 01 Value                            6.00
ASSUM02      ECO Assumption 02               ECO density for FH (ksf)
ASSUM02V     ECO Assumption 02 Value                            1.50
ASSUM03      ECO Assumption 03           Efficiency of gas Water Heat
ASSUM03V     ECO Assumption 03 Value                            0.55
ASSUM04      ECO Assumption 04         Efficiency of elect. Wtr. Heat
ASSUM04V     ECO Assumption 04 Value                            0.97
ASSUM05      ECO Assumption 05                          Tank R-Value
ASSUM05V     ECO Assumption 05 Value                            6.00
ASSUM06      ECO Assumption 06                       Blanket R-Value
ASSUM06V     ECO Assumption 06 Value                            5.00
ASSUM07      ECO Assumption 07                      Tank Temperature
ASSUM07V     ECO Assumption 07 Value                          150.00
ASSUM08      ECO Assumption 08                      Room Temperature
ASSUM08V     ECO Assumption 08 Value                           70.00
ASSUM09      ECO Assumption 09                          Surface Area
ASSUM09V     ECO Assumption 09 Value                           25.13
ASSUM10      ECO Assumption 10                Annual hours of operation
ASSUM10V     ECO Assumption 10 Value                         8760.00
```

Rules file.

```
* This is the wateblan.prg program

* SECTION 1 - ECO specific calculations

********** Select the Penetration Factor **********

do comcalc

********** calculate number of ECO units **********

* numecouni start

replace numecouni ;
   with xfamhouare / xassum02v + ( xtraare + xadmare + ;
        xcomfacare ) / xassum01v * ( 1 - penfac )

* numecouni end

**********Select Project Size Factor**********

do comcalc0

**********Calculate Adjusted Initial Cost********

* inicos start

replace inicos ;
   with numecouni * xlocind * xcapcost * prosizfac

* inicos end

********** calculate base load fuel saved **********

* basdemsav start

replace basdemsav ;
   with 0

* basdemsav end

******** calculate summer demand fuel saved*******

* sumdemsav start

replace sumdemsav ;
   with 0

* sumdemsav end
```

```
********** calculate heating energy saved **********

* heaenesav start

replace heaenesav ;
   with numecouni * ( ( ( 1 / xassum05v ) * xassum09v * ( ;
        xassum07v - xassum08v ) * xassum10v / 1000000 ) - ;
        ( ( 1 / ( xassum05v + xassum06v ) ) * xassum09v * ;
        ( xassum07v - xassum08v ) * xassum10v / 1000000 ) )

* heaenesav end

********** calculate cooling energy saved **********

* cooenesav start

replace cooenesav ;
   with 0

* cooenesav end

********** calculate electric fuel saved **********

* eleenesav start

if ( xghp75cap + xghp75con ) = 0
       replace eleenesav ;
          with heaenesav / xassum04v
else
             x = xghp75con + xohp75con + xchp75con
             if x = 0
             replace eleenesav ;
                with 0
       else
             replace eleenesav ;
                with heaenesav / xassum04v * ( 1 - ;
                     ( xghp75con / ( xghp75con + xohp75con + ;
                     xchp75con ) ) )
       endif
endif

* eleenesav end

********** calculate gas fuel saved **********

* gasenesav start

if xghp75cap + xghp75con > 0
       x = xghp75con + xohp75con + xchp75con
       if x = 0
             replace gasenesav ;
```

```
                    with 0
        else
              replace gasenesav ;
                 with ( heaenesav / xassum03v ) * ;
                      xghp75con / ( xghp75con + xohp75con + ;
                      xchp75con )
        endif
else
        replace gasenesav ;
           with 0
endif

* gasenesav end

********** calculate oil fuel saved **********

* oilenesav start

replace oilenesav ;
   with 0

* oilenesav end

********** calculate coal fuel saved **********

* coaenesav start

replace coaenesav ;
   with 0

* coaenesav end

********** calculate water saved **********

* watvolsav start

replace watvolsav ;
   with 0

* watvolsav end

***** Calculate Lbs. of CFCs displaced *****

* cfcdisp start

replace cfcdisp ;
        with 0

* cfcdisp end

* SECTION 2 - Common calculations and HVAC calculations
do comcalc1
```

```
********** calculate water cost saved **********

* watcossav start

replace watcossav ;
   with 0

* watcossav end

********** calculate HVAC energy cost saved **********

* henecossav start

replace henecossav ;
   with 0

* henecossav end

do comcalc2

* SECTION 3 - ECO specific calculations that override common calculations
```

Appendix E: REEP Summary Reports

This appendix contains example printouts of the following four summary reports available for all 89 Army installations in the REEP database:

1. REEP Composite Summary Report
2. REEP Financial Summary Report
3. REEP Resource Savings Report
4. REEP Pollution Summary Report.

Brief descriptions of each report follow.

REEP Composite Summary Report

This is a one-page summary describing potential resource, financial, and pollution savings at the installation(s) being analyzed. Actual resource consumption for the installation(s) being examined are compared to REEP estimated savings to determine percentage savings potential. Actual utility costs are compared to estimated utility savings to determine dollar savings percentage, and calculated current pollution estimates are compared to REEP estimated pollution reductions to determine pollution savings percentages. Also included at the bottom of the report is an energy target summary that compares 1985 consumption to current consumption values to see if the installation has increased or decreased its consumption over time. This is a very useful report in that it provides a lot of information at a macro-level on a single page printout.

REEP Financial Summary Report

This provides the financial details of ECO/WCO analysis. It can be run for one or numerous installations. Each ECO/WCO is reported on a single row with the following information: number of units, units, total investment, total net discounted savings, annual savings, simple payback, savings-to-investment ratio, adjusted internal rate of return, and societal savings. If all the ECOs/WCOs are run for one installation, this report provides a good overview of where financial savings may be found.

REEP Resource Summary Report

This report provides the resource savings for each ECO/WCO that has been selected for the analysis. Reported are: Demand Savings (KW), Electrical Savings (MBtu/Yr), Gas Savings (MBtu/Yr), Oil Savings (MBtu/Yr), Coal Savings (MBtu/Yr), Total Savings (MBtu/Yr), and Water Savings (Kgal/Yr). If all ECOs/WCOs are run for only one installation, this report provides a good overview of where energy and water savings may be found.

REEP Pollution Summary Report

This report provides the pollution savings for each ECO/WCO selected for the analysis, including SOx (Tons/Yr), NOx (Tons/Yr), Particulates (Tons/Yr), CO (Tons/Yr), CO_2 (Tons/Yr), Hydrocarbons (Tons/Yr), CFCs (Lb/Yr).

All reports can be run for one, several, or all of the installations in the REEP database depending on the users needs.

Other REEP Reporting Capabilities

Some other reporting capabilities in REEP:

- All of the values contained for an installation in the installation database can be printed out for a particular installation. This report allows a user to obtain a hardcopy of the values being used in the analysis, review them, and go back into the program to modify if necessary.
- A single-page printout of the results of an analysis of a single ECO or WCO at one installation provides the installation database values used, ECO or WCO values used, and the financial, resource, and pollution results.

REEP COMPOSITE SUMMARY REPORT Page 1

11/01/94

TOTAL INVESTMENT	$1,036,102,321
TOTAL NET DISCOUNTED SAVINGS	$3,010,394,201
TOTAL ANNUAL SAVINGS	$203,106,133
COMPOSITE SIMPLE PAYBACK - YEARS	5.10

RESOURCE SAVINGS	ACTUAL CONSUMPTION	UNITS	REEP ESTIMATED SAVINGS	PERCENT SAVINGS
Demand	1,951,825	kW	400,431	20.52
Electric	29,774,405	MBtu/Yr	5,520,522	18.54
Gas	35,720,130	MBtu/Yr	9,893,369	27.70
Oil	11,511,465	MBtu/Yr	4,157,708	36.12
Coal	9,321,763	MBtu/Yr	883,066	9.47
Total	86,327,763	MBtu/Yr	20,454,665	23.69
Water	96,605,871	KGal	12,755,310	13.20
Sewage	73,395,672	KGal		

FINANCIAL SAVINGS	ACTUAL COSTS	UNITS	REEP ESTIMATED SAVINGS	PERCENT SAVINGS
Demand		Dollars	$ 39,057,076	
Electric		Dollars	$ 70,541,597	
Total	$443,643,897	Dollars	$109,598,673	24.70
Gas		Dollars	$ 43,358,159	
Oil		Dollars	$ 20,829,139	
Coal		Dollars	$ 1,932,939	
Total	$298,382,308	Dollars	$ 66,120,237	22.16
Water	$42,498,739	Dollars		
Sewage	$45,700,280	Dollars		
Total	$88,199,019	Dollars	$ 17,708,408	20.08
Totals	$830,225,224	Dollars	$193,427,318	23.30
Societal Savings		Dollars	$ 82,060,467	

POLLUTION SAVINGS	CURRENT POLLUTION ESTIMATE	UNITS	REEP ESTIMATED REDUCTION	PERCENT REDUCTION
SOx	72,504.23	Tons/Yr	10,277.84	14.17
NOx	28,075.28	Tons/Yr	4,883.66	17.39
Particulate	3,604.44	Tons/Yr	688.62	19.10
CO	2,939.68	Tons/Yr	558.64	19.00
CO2	10,851,937.41	Tons/Yr	2,256,199.80	20.79
Hydrocarbons	210.74	Tons/Yr	40.44	19.18
Total	10,959,271.81	Tons/Yr	2,272,649.00	20.73
CFCs		Lbs/Yr	214,500.00	

ENERGY TARGET SUMMARY			CONSERVATION POTENTIAL
1985 Energy Consumption	(MBtu)	84,561,085	1993 REEP Resource
1985 Building Sq. Ft.	(KSF)	663,698	Savings Potential
1985 Energy Use Intensity	(KBtu/SF)	127	20,454,665 (MBtu/Yr)
1993 Energy Consumption	(MBtu)	86,327,763	Actual 85/93 Reduction 10.15%
1993 Building Sq. Ft.	(KSF)	754,112	Potntl 85/93 Reduction 31.44%
1993 Energy Use Intensity	(KBtu/SF)	114	

REEP FINANCIAL SUMMARY REPORT

07/18/95

ECO Type / ECO	ECO Units	Unit	Total Investment ($)	Total Net Dis. Savings ($)	Annual Savings ($)	Simp Paybk (Yrs)	SIR	AIRR (%)	Societal Savings ($)
Electrical									
High Eff Motors (Large)	3354	Motors	5115273	18731167	1228726	4.16	3.66	10.97	977374
High Eff Motors (Medium)	3807	Motors	3638854	13029661	854681	4.26	3.58	10.85	680797
High Eff Motors (Small)	37781	Motors	15762595	47330102	3104637	5.08	3.00	9.87	2537520
Ventln Motor ASD (Large)	28	Motors	213360	348935	39776	5.36	1.64	9.27	22070
Ventln Motor ASD (Medium)	228	Motors	888037	1623909	185413	4.79	1.83	10.48	96969
Ventln Motor ASD (Small)	1253	Motors	2203197	3116574	357062	6.17	1.41	7.64	129319
Envelope									
6.5 Inch Addtnl Clg Insul	10020645	Sq. Ft.	5297109	17839094	979313	5.41	3.37	10.51	657937
Ext Insul Finish Sys	0	Sq. Ft.	0	0	0	0.00	0.00	0.00	0
FH 6.0 Inch Addtnl Clg In	4914020	Sq. Ft.	3329865	7265725	411431	8.09	2.18	8.13	199276
FH Rockwool Wall Insulati	10942254	Sq. Ft.	10803370	28445919	1610896	6.71	2.63	9.15	785600
High Reflctnce Roof Membr	0	Sq. Ft.	0	0	0	0.00	0.00	0.00	0
Radiant Barriers	10051200	Sq. Ft.	3421945	8161477	502481	6.81	2.39	8.63	216968
Shading Devices	0	Sq. Ft.	0	0	0	0.00	0.00	0.00	0
Storm Windows	0	Sq. Ft.	0	0	0	0.00	0.00	0.00	0
Window Film	2025041	Sq. Ft.	4095200	7978684	835569	4.90	1.95	11.18	559541
Heating/Cooling									
Desiccant Cooling	613	Unit	13443418	23590180	2069178	6.50	1.75	6.95	1127302
Enthalpy Recvry Desscnt W	732	Wheels	2467476	6598785	403820	6.11	2.67	11.04	359817
Evap. Pre-Cool Air	0	Units	0	0	0	0.00	0.00	0.00	0
FH Desuperheaters	6544	Desprhtrs	4048361	7923843	496958	8.15	1.96	7.56	604273
FH Duct Seals	50786	Houses	7177141	72819583	4147696	1.73	10.15	16.78	2222765
FH Flame Ret. Burners	2221	Burners	1287101	7061324	523021	2.46	5.49	16.50	286311
FH Gas Engine Drvn HP	242	Heat Pumps	2129389	9012604	587067	3.63	4.23	11.78	274479
FH Ground Source HP	17842	Heat Pumps	63277208	236725670	13346535	4.74	3.74	11.09	-1886801
FH Heat Pumps	29911	Heat Pumps	61559496	151268217	8507389	7.24	2.46	8.79	3076960
FH HiEff Gas Furn	0	Furnaces	0	0	0	0.00	0.00	0.00	0
FH HiEff Oil Furn	13665	Furnaces	14115362	39197146	2244534	6.29	2.78	9.45	1235734
FH High SEER AC	835	ACs	1055359	2288135	149260	7.07	2.17	8.11	46300
FH Insulate Ducts	2611740	Sq. Ft.	6504001	15323786	875589	7.43	2.36	8.56	647259
FH Nom Eff Gas Furn	5147	Furnaces	4119223	11514697	580593	7.09	2.80	9.49	76498
FH Progrmmbl Thermostats	60995	Thermstats	5598303	18625824	1264547	4.43	3.33	12.68	666226
FH Whole House Fans w/AC	5255	Fans	3425222	10710436	686707	4.99	3.13	10.11	186354
Flame Retention Burners	1112	Burners	1033975	12881986	952985	1.08	12.46	23.05	526216
Gas Hieff Boilers	3037	Boilers	21187575	42905379	2811239	7.54	2.03	9.03	622353
Gas Nomeff Boiler	1	Boilers	4436	7454	470	9.44	1.68	7.66	91
Oil Nomeff Boiler	1339	Boilers	6842930	14558505	1077330	6.35	2.13	9.38	595148
SLDC Panels	7761	Panels	95390888	260165934	14910523	6.40	2.73	9.36	9495043
Ventilation Heat Recovery	7401	Heat Exchs	21874899	80345205	4177247	5.24	3.67	10.99	1901469
Lighting									
4' Fluorescent Ltng	1781094	Fixtures	213331598	381587013	31579488	6.76	1.79	8.12	15879114

REEP FINANCIAL SUMMARY REPORT

ARMY INSTALLATIONS

07/18/95

ECO Type ECO	ECO Units	Unit	Total Investment ($)	Total Net Dis. Savings ($)	Annual Savings ($)	Simp Paybk (Yrs)	SIR	AIRR (%)	Societal Savings ($)
Compact Fluorescent Ltng	563762	Lamps	5515778	61426896	5083554	1.09	11.14	22.13	2719903
Constant Level Lighting	837	Contrllrs	109025	145362	11893	9.17	1.33	6.00	1501
Exit Lighting	142235	Fixtures	6647892	80270063	6714314	0.99	12.07	22.79	1937099
High Pressure Sodium Lght	14687	Lamps	2926067	5292786	437301	6.69	1.81	8.20	232107
High wattage incand replc	123360	Fixtures	24784031	48388925	4005767	6.19	1.95	8.73	1984145
Occupancy Sensor	156132	Sensors	11559236	22461186	1819863	6.35	1.94	8.70	1178263
Miscellaneous									
Efficient Computers	0	Computers	0	0	0	0.00	0.00	0.00	0
FH Hot Water Heat Pump	687	Heat Pumps	1003473	2422541	119677	8.38	2.41	8.68	33123
FH Tankless Water Heaters	0	Heaters	0	0	0	0.00	0.00	0.00	0
High Eff Refrig Replcmnt	9644	Refrgrtrs	6077834	12301778	790126	7.69	2.02	7.72	287916
Wtr Htr Insulation Blanke	107653	Blankets	2172090	12227861	1291057	1.68	5.63	23.62	610343
Renewables									
Barracks Solar Water Htg	0	Barracks	0	0	0	0.00	0.00	0.00	0
FH Passive Solar Sunspace	0	Rooms	0	0	0	0.00	0.00	0.00	0
FH Solar Water Htg	2173	Houses	5524274	10212308	651388	8.48	1.85	7.25	123783
Microclimate Modification	13240	Houses	4493454	13410655	795018	5.65	2.98	9.84	664145
Photovoltaic Peaking Stat	0	Kw	0	0	0	0.00	0.00	0.00	0
Solar Street Lighting	0	Fixtures	0	0	0	0.00	0.00	0.00	0
SolarWall for Maint Bldgs	755981	Sq. Ft.	13337508	40427664	2158582	6.18	3.03	9.93	1107707
Wind Energy	148	Turbines	4776952	9216742	593980	8.04	1.93	7.48	300648
Utilities									
Amorphs Core Transfrmrs	485898	KVAR	27712094	51263728	3325734	8.33	1.85	7.25	811685
Cogen - Fuel Cell	0	Fuel Cells	0	0	0	0.00	0.00	0.00	0
Cogen - Gas Turbine	0	Turbines	0	0	0	0.00	0.00	0.00	0
Cogen - Recip. Engine	0	Engines	0	0	0	0.00	0.00	0.00	0
DF NG Chllrs 5-50 Tons	0	Chillers	0	0	0	0.00	0.00	0.00	0
DF NG Chllrs 50-100 Tons	0	Chillers	0	0	0	0.00	0.00	0.00	0
DF NG Chllrs >100 Tons	0	Chillers	0	0	0	0.00	0.00	0.00	0
EMCS	0	Points	0	0	0	0.00	0.00	0.00	0
Gas Engine Air Compressor	2	Engines	127008	443203	33300	3.81	3.49	10.71	16410
Gas Engine Water Pump	83	Engines	7459855	19945976	1771825	4.21	2.67	9.23	1116704
GasEng Chllrs 5-50 Tons	0	Chillers	0	0	0	0.00	0.00	0.00	0
GasEng Chllrs 50-100 Tons	20	Chillers	1029559	1868478	152111	6.77	1.81	7.13	113088
GasEng Chllrs >100 Tons	140	Chillers	21551596	36921011	2952260	7.30	1.71	6.83	2278248
HiEff Chllrs 5-50 Tons	0	Chillers	0	0	0	0.00	0.00	0.00	0
HiEff Chllrs 50-100 Tons	68	Chillers	2423759	4114329	273077	8.88	1.70	6.80	108790
HiEff Chllrs >100 Tons	278	Chillers	30397448	99378191	6480119	4.69	3.27	10.35	3409120
Manhl Sump-Pmp I/R Prgrm	1393	Units	1499711	91265467	4594330	0.33	60.86	27.72	4228951
Storage Cooling Systems	126016	Ton-Hours	15094416	29362867	2477879	6.09	1.95	8.73	0
Undrgrnd Heat Dist Sys Rp	366	Repairs	1821774	50416209	2659224	0.69	27.67	22.78	2023257

REEP FINANCIAL SUMMARY REPORT

ARMY INSTALLATIONS

07/18/95

ECO Type ECO	ECO Units	Unit	Total Investment ($)	Total Net Dis. Savings ($)	Annual Savings ($)	Simp Paybk (Yrs)	SIR	AIRR (%)	Societal Savings ($)
Water									
FH Ultra Low Flow Toilets	93038	Toilets	30755494	101738888	6895683	4.46	3.31	10.41	46856
Faucet Aerators	163377	Aerators	869246	8714349	971584	0.89	10.03	30.97	280623
Flush Valve Retrofits	72447	Valves	633639	26608424	3131856	0.20	41.99	51.13	84737
Horizntl Axis Washng Mchn	4324	Machines	2730277	4725487	383477	7.12	1.73	7.87	116849
Low-flow Shower Head	54458	Shwr Heads	1214194	25555575	2840075	0.43	21.05	41.05	866063
Water Consrvng Dishwshrs	0	Dishwshrs	0	0	0	0.00	0.00	0.00	0
Water Distibtn Leak Repai	7030	Repairs	7434084	43016858	2897284	2.57	5.79	13.54	565350
Totals			846323934	2472526760	167814499	5.04	2.92		72053696

REEP RESOURCE SUMMARY REPORT

ARMY INSTALLATIONS

07/18/95

ECO Type / ECO	Demand Savings (KW)	Electric Savings (MBtu/Yr)	Gas Savings (MBtu/Yr)	Oil Savings (MBtu/Yr)	Coal Savings (MBtu/Yr)	Total Savings (MBtu/Yr)	Water Savings (KGals/Yr)
Electrical							
High Eff Motors (Large)	5362	85485	0	0	0	85485	0
High Eff Motors (Medium)	3735	59536	0	0	0	59536	0
High Eff Motors (Small)	13205	210868	0	0	0	210868	0
Ventln Motor ASD (Large)	0	2597	0	0	0	2597	0
Ventln Motor ASD (Medium)	0	11935	0	0	0	11935	0
Ventln Motor ASD (Small)	0	19850	0	0	0	19850	0
Envelope							
6.5 Inch Addtnl Clg Insul	14	20859	117707	55284	20023	213873	0
Ext Insul Finish Sys	0	0	0	0	0	0	0
FH 6.0 Inch Addtnl Clg Insul	0	2837	20072	53223	0	76132	0
FH Rockwool Wall Insulation	16	28221	116080	141878	55	286234	0
High Reflctnce Roof Membrn	0	0	0	0	0	0	0
Radiant Barriers	10	24015	16131	4125	6	44277	0
Shading Devices	0	0	0	0	0	0	0
Storm Windows	0	0	0	0	0	0	0
Window Film	1	8789	106269	56917	23916	195891	0
Heating/Cooling							
Desiccant Cooling	22295	112922	-390063	0	0	-277141	0
Enthalpy Recvry Desscnt Wheel	49	883	50602	107314	654	159453	0
Evap. Pre-Cool Air	0	0	0	0	0	0	0
FH Desuperheaters	737	38471	18314	0	0	56785	0
FH Duct Seals	0	182692	493936	0	0	676628	0
FH Flame Ret. Burners	0	0	0	103947	0	103947	0
FH Gas Engine Drvn HP	710	36593	-95073	0	0	-58480	0
FH Ground Source HP	24005	-70134	1474239	0	0	1404105	0
FH Heat Pumps	33652	193154	1112469	0	0	1305623	0
FH HiEff Gas Furn	0	0	0	0	0	0	0
FH HiEff Oil Furn	0	0	0	448670	0	448670	0
FH High SEER AC	940	6609	0	0	0	6609	0
FH Insulate Ducts	0	17506	63049	49957	35923	166435	0
FH Nom Eff Gas Furn	0	-3821	136822	0	0	133001	0
FH Progrmmbl Thermostats	0	35	234140	82640	28992	345807	0
FH Whole House Fans w/AC	0	37871	0	0	0	37871	0
Flame Retention Burners	0	0	0	191001	0	191001	0
Gas Hieff Boilers	0	0	692338	0	0	692338	0
Gas Nomeff Boiler	0	0	96	0	0	96	0
Oil Nomeff Boiler	0	0	0	216037	0	216037	0
SLDC Panels	0	414452	1305896	747686	207113	2675147	0
Ventilation Heat Recovery	424	9996	697572	327550	32717	1067835	0
Lighting							
4' Fluorescent Ltng	117945	1464848	-86899	-72324	-16413	1289212	0

REEP RESOURCE SUMMARY REPORT

ARMY INSTALLATIONS

07/18/95

ECO Type ECO	Demand Savings (KW)	Electric Savings (MBtu/Yr)	Gas Savings (MBtu/Yr)	Oil Savings (MBtu/Yr)	Coal Savings (MBtu/Yr)	Total Savings (MBtu/Yr)	Water Savings (KGals/Yr)
Compact Fluorescent Ltng	29060	257803	-19139	-11667	-3769	223228	0
Constant Level Lighting	32	282	-24	-6	0	252	0
Exit Lighting	5907	176617	-14182	-7896	-2249	152290	0
High Pressure Sodium Lghts	2277	20199	0	0	0	20199	0
High wattage incand replcmnt	20217	179364	-10843	-10855	-2634	155032	0
Occupancy Sensor	0	110819	-3930	-3782	-58	103049	0
Miscellaneous							
Efficient Computers	0	0	0	0	0	0	0
FH Hot Water Heat Pump	0	557	18335	0	0	18892	0
FH Tankless Water Heaters	0	0	0	0	0	0	0
High Eff Refrig Replcmnt	0	42777	0	0	0	42777	0
Wtr Htr Insulation Blanket	0	49565	173709	0	0	223274	0
Renewables							
Barracks Solar Water Htg	0	0	0	0	0	0	0
FH Passive Solar Sunspace	0	0	0	0	0	0	0
FH Solar Water Htg	0	35471	1426	0	0	36897	0
Microclimate Modifications	8475	72523	40400	-2628	2902	113197	-144978
Photovoltaic Peaking Station	0	0	0	0	0	0	0
Solar Street Lighting	0	0	0	0	0	0	0
SolarWall for Maint Bldgs	0	0	325139	174790	42530	542459	0
Wind Energy	1147	34283	0	0	0	34283	0
Utilities							
Amorphs Core Transfrmrs	4665	139433	0	0	0	139433	0
Cogen - Fuel Cell	0	0	0	0	0	0	0
Cogen - Gas Turbine	0	0	0	0	0	0	0
Cogen - Recip. Engine	0	0	0	0	0	0	0
DF NG Chllrs 5-50 Tons	0	0	0	0	0	0	0
DF NG Chllrs 50-100 Tons	0	0	0	0	0	0	0
DF NG Chllrs >100 Tons	0	0	0	0	0	0	0
EMCS	0	0	0	0	0	0	0
Gas Engine Air Compressors	166	1538	-4132	0	0	-2594	0
Gas Engine Water Pump	17198	128518	-345363	0	0	-216845	0
GasEng Chllrs 5-50 Tons	0	0	0	0	0	0	0
GasEng Chllrs 50-100 Tons	1238	12420	-28319	0	0	-15899	-1235
GasEng Chllrs >100 Tons	24752	244639	-603441	0	0	-358802	-24333
HiEff Chllrs 5-50 Tons	0	0	0	0	0	0	0
HiEff Chllrs 50-100 Tons	1143	13853	0	0	0	13853	0
HiEff Chllrs >100 Tons	20016	350366	0	0	0	350366	0
Manhl Sump-Pmp I/R Prgrm	0	0	971643	310799	318330	1600772	0
Storage Cooling Systems	22054	0	0	0	0	0	0
Undrgrnd Heat Dist Sys Rprs	0	0	465007	147467	152724	765198	0

REEP RESOURCE SUMMARY REPORT

ARMY INSTALLATIONS

07/18/95

ECO Type ECO	Demand Savings (KW)	Electric Savings (MBtu/Yr)	Gas Savings (MBtu/Yr)	Oil Savings (MBtu/Yr)	Coal Savings (MBtu/Yr)	Total Savings (MBtu/Yr)	Water Savings (KGals/Yr)
Water							
FH Ultra Low Flow Toilets	0	6537	0	0	0	6537	2390703
Faucet Aerators	0	25516	60150	0	0	85666	245970
Flush Valve Retrofits	0	8029	0	0	0	8029	1627075
Horizntl Axis Washng Mchns	0	6641	5897	6542	2926	22006	24464
Low-flow Shower Head	0	78577	186728	0	0	265305	651952
Water Consrvng Dishwshrs	0	0	0	0	0	0	0
Water Distibtn Leak Repair	0	47604	0	0	0	47604	6321758
Totals	381447	4961000	7302758	3116669	843688	16224115	11091376

REEP POLLUTION SUMMARY REPORT

ARMY INSTALLATIONS

07/18/95

ECO Type / ECO	SOx (Tons/Yr)	NOx (Tons/Yr)	Part (Tons/Yr)	CO (Tons/Yr)	CO2 (Tons/Yr)	HC (Tons/Yr)	CFC (Lbs/Yr)
Electrical							
High Eff Motors (Large)	147.96	59.79	8.88	3.18	18931.33	0.42	0.00
High Eff Motors (Medium)	103.07	41.60	6.22	2.17	13184.20	0.31	0.00
High Eff Motors (Small)	384.95	154.54	23.02	8.25	48999.23	1.15	0.00
Ventln Motor ASD (Large)	2.88	1.41	0.26	0.09	547.51	0.01	0.00
Ventln Motor ASD (Medium)	13.52	5.81	0.93	0.44	2230.60	0.04	0.00
Ventln Motor ASD (Small)	19.03	7.04	1.05	0.64	2795.08	0.06	0.00
Envelope							
6.5 Inch Addtnl Clg Insul	84.62	34.53	3.62	5.90	18318.77	0.23	0.00
Ext Insul Finish Sys	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FH 6.0 Inch Addtnl Clg Insul	24.08	8.52	1.19	1.36	6228.36	0.09	0.00
FH Rockwool Wall Insulation	84.53	40.70	6.78	5.87	26435.57	0.44	0.00
High Reflctnce Roof Membrn	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Radiant Barriers	19.13	14.70	3.72	1.63	7819.05	0.21	0.00
Shading Devices	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Storm Windows	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Window Film	74.03	26.82	2.46	5.55	15377.92	0.16	0.00
Heating/Cooling							
Desiccant Cooling	231.64	63.62	12.10	-2.46	3949.14	0.46	0.00
Enthalpy Recvry Dessent Wheel	39.96	15.20	2.02	2.82	12341.42	0.16	0.00
Evap. Pre-Cool Air	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FH Desuperheaters	98.53	32.58	4.63	1.72	10278.69	0.19	0.00
FH Duct Seals	214.17	156.71	25.09	17.22	76214.39	1.48	0.00
FH Flame Ret. Burners	35.66	10.49	1.75	1.81	8835.51	0.14	0.00
FH Gas Engine Drvn HP	40.61	12.79	6.24	0.57	5424.65	0.34	0.00
FH Ground Source HP	-757.39	-56.87	20.08	30.68	90711.65	1.90	0.00
FH Heat Pumps	289.26	221.77	20.94	27.08	109487.06	1.37	0.00
FH HiEff Gas Furn	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FH HiEff Oil Furn	153.92	45.25	7.54	7.78	38137.04	0.54	0.00
FH High SEER AC	8.16	2.04	0.27	0.14	675.14	0.00	0.00
FH Insulate Ducts	90.72	30.81	3.95	6.54	16103.42	0.28	0.00
FH Nom Eff Gas Furn	-7.68	7.00	-0.16	2.19	7101.47	0.01	0.00
FH Progrmmbl Thermostats	71.16	32.90	2.18	8.40	23395.01	0.17	0.00
FH Whole House Fans w/AC	18.15	18.03	2.31	1.07	5705.73	0.12	0.00
Flame Retention Burners	65.55	19.31	3.20	3.34	16235.18	0.19	0.00
Gas Hieff Boilers	0.19	47.42	1.01	11.76	39809.47	0.19	0.00
Gas Nomeff Boiler	0.00	0.01	0.00	0.00	5.52	0.00	0.00
Oil Nomeff Boiler	74.14	21.79	3.64	3.77	18363.27	0.22	0.00
SLDC Panels	1235.33	515.04	64.33	73.51	256017.09	4.21	0.00
Ventilation Heat Recovery	177.62	97.86	8.09	21.41	73572.60	0.74	0.00
Lighting							
4' Fluorescent Ltng	2336.73	1003.98	154.05	54.04	321972.35	7.89	0.00

REEP POLLUTION SUMMARY REPORT

ARMY INSTALLATIONS

07/18/95

ECO Type ECO	SOx (Tons/Yr)	NOx (Tons/Yr)	Part (Tons/Yr)	CO (Tons/Yr)	CO2 (Tons/Yr)	HC (Tons/Yr)	CFC (Lbs/Yr)
Compact Fluorescent Ltng	391.68	179.08	27.09	9.31	56729.14	1.34	0.00
Constant Level Lighting	0.16	0.13	0.02	0.01	43.46	0.00	0.00
Exit Lighting	289.51	122.31	18.29	6.18	38056.57	0.91	0.00
High Pressure Sodium Lghts	34.17	14.91	2.16	0.78	4689.99	0.05	0.00
High wattage incand replcmnt	295.07	126.22	18.97	6.37	39265.54	0.94	0.00
Occupancy Sensor	171.81	71.91	11.95	4.37	24583.86	0.60	0.00
Miscellaneous							
Efficient Computers	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FH Hot Water Heat Pump	2.85	0.66	0.32	0.42	1449.11	0.03	0.00
FH Tankless Water Heaters	0.00	0.00	0.00	0.00	0.00	0.00	0.00
High Eff Refrig Replcmnt	28.45	20.06	4.87	1.92	9405.87	0.28	0.00
Wtr Htr Insulation Blanket	60.39	39.74	5.73	4.99	21055.05	0.30	0.00
Renewables							
Barracks Solar Water Htg	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FH Passive Solar Sunspace	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FH Solar Water Htg	15.76	6.66	0.22	1.07	3555.25	0.01	0.00
Microclimate Modifications	63.01	50.46	10.21	4.73	22152.21	0.58	0.00
Photovoltaic Peaking Station	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solar Street Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SolarWall for Maint Bldgs	122.67	52.33	4.07	12.97	37805.77	0.39	0.00
Wind Energy	45.12	19.52	2.72	0.94	5806.92	0.13	0.00
Utilities							
Amorphs Core Transfrmrs	116.88	46.37	5.92	4.26	18162.93	0.32	0.00
Cogen - Fuel Cell	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cogen - Gas Turbine	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cogen - Recip. Engine	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DF NG Chllrs 5-50 Tons	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DF NG Chllrs 50-100 Tons	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DF NG Chllrs >100 Tons	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EMCS	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gas Engine Air Compressors	3.13	0.96	0.17	-0.01	126.74	0.00	0.00
Gas Engine Water Pump	204.63	74.10	12.73	-0.86	9859.19	0.55	0.00
GasEng Chllrs 5-50 Tons	0.00	0.00	0.00	0.00	0.00	0.00	0.00
GasEng Chllrs 50-100 Tons	19.47	7.74	1.25	0.03	1350.84	0.05	3080.00
GasEng Chllrs >100 Tons	374.61	177.07	29.61	-0.40	29151.81	1.42	61600.00
HiEff Chllrs 5-50 Tons	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HiEff Chllrs 50-100 Tons	10.30	10.28	1.25	0.69	3465.98	0.07	10472.00
HiEff Chllrs >100 Tons	410.33	234.61	47.52	16.92	91567.81	2.48	122320.00
Manhl Sump-Pmp I/R Prgrm	575.50	190.89	11.48	55.09	114120.52	1.30	0.00
Storage Cooling Systems	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Undrgrnd Heat Dist Sys Rprs	275.53	91.34	5.46	26.33	54545.06	0.57	0.00
Water							
FH Ultra Low Flow Toilets	3.00	3.74	1.06	0.38	1913.23	0.06	0.00

REEP POLLUTION SUMMARY REPORT

ARMY INSTALLATIONS

07/18/95

ECO Type ECO	SOx (Tons/Yr)	NOx (Tons/Yr)	Part (Tons/Yr)	CO (Tons/Yr)	CO2 (Tons/Yr)	HC (Tons/Yr)	CFC (Lbs/Yr)
Faucet Aerators	29.74	18.30	2.74	2.03	9069.52	0.12	0.00
Flush Valve Retrofits	11.90	5.82	0.86	0.31	1825.82	0.00	0.00
Horizntl Axis Washng Mchns	17.64	5.73	0.80	0.78	2494.83	0.05	0.00
Low-flow Shower Head	91.65	56.54	8.56	6.48	28004.81	0.50	0.00
Water Consrvng Dishwshrs	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Distibtn Leak Repair	86.48	35.11	5.12	1.69	10623.17	0.25	0.00
Totals	9125.67	4355.78	642.54	476.25	1936084.42	37.02	197472.00

List of Abbreviations and Acronyms

AIRR	adjusted internal rate of return
AR	Army Regulation
ASD	adjustable speed drive
BASDEM	baseload demand cost
CAA	Concepts Analysis Agency
CCB	Construction Criteria Database
CDD	cooling degree day
CFC	chlorofluorocarbon
CONUS	Continental United States
CO_2	carbon dioxide
CO	carbon monoxide
COP	coefficient of performance
DEIS	Defense Energy Information System
DEPPM	Defense Energy Program Policy Memorandum
DOD	Department of Defense
DOE	Department of Energy
DSM	Demand Side Management
ECIP	Energy Conservation Investment Program
ECO	energy conservation opportunities
EIFS	Exterior Insulation Finish System
EMCS	Energy Monitoring Control System
FH	family housing
FORSCOM	U.S. Army Forces Command
GIGO	garbage in - garbage out

HFC	hydrofluorocarbon
HID	high intensity discharge
HP	horsepower
HVAC	heating, ventilating, and air-conditioning
HC	hydrocarbon
HDD	heating degree day
LCD	liquid crystal diode
LED	light emitting diode
MCWB	mean coincident wet bulb
MH	metal halide
MILCON	Military Construction
mWh	megaWatt hour
NFESC	Naval Facilities Engineering Services Center
NIBS	National Institute of Building Sciences
NIST	National Institute of Standards and Technology
NO_x	nitrogen oxide
ODUSD/ES/C&I	Office of the Deputy Undersecretary of Defense/Environmental Security/Conservation & Installations
PM	particulate matter
PV	photovoltaic
R&D	research and development
RDBMS	relational database management system
REEP	Renewables and Energy Efficiency Planning
RPDB	real property database
SERDP	Strategic Environmental Research and Development Program
SIOH	site inspection and overhead
SIR	savings-to-investment ratio
SLDC	Single-Loop Digital Control

SPV	Single Present Value
SO_2	sulfur dioxide
SUMDEM	summer demand cost
TM	technical manual
UPA	utility procurement analysis
UPV	Uniform Present Value
USACERL	U.S. Army Construction Engineering Research Laboratories
USACPW	U.S. Army Center for Public Works (formerly USAEHSC)
USAEHSC	U.S. Army Engineering and Housing Support Center (now USACPW)
USEPA	U.S. Environmental Protection Agency
WCO	water conservation opportunity

Distribution

Chief of Engineers
ATTN: CEHEC-IM-LH (2)
ATTN: CEHEC-IM-LP (2)
ATTN: CECG
ATTN: CECC-P
ATTN: CECC-R
ATTN: CECW
ATTN: CECW-O
ATTN: CECW-P
ATTN: CECW-PR
ATTN: CEMP
ATTN: CEMP-E
ATTN: CEMP-C
ATTN: CEMP-M
ATTN: CEMP-R
ATTN: CERD-C
ATTN: CERD-ZA
ATTN: CERD-L
ATTN: CERD-M
ATTN: CERM
ATTN: DAEN-ZC
ATTN: DAIM-FDP

CECPW 22310-3862
ATTN: CECPW-E
ATTN: CECPW-FT
ATTN: CECPW-ZC

US Army Engr District
ATTN: Library (38)

US Army Engr Division
ATTN: Library (9)

US Army Materiel Command (AMC)
Alexandria, VA 22333-0001
ATTN: AMCEN-F

FORSCOM
Forts Gillem & McPherson 30330
ATTN: FCEN

TRADOC
Fort Monroe 23651
ATTN: ATBO-G

Fort Belvoir 22060
ATTN: CETEC-IM-T
ATTN: CETEC-ES 22315-3803
ATTN: Water Resources Support Ctr

Engr Societies Library
ATTN: Acquisitions 10017

Defense Logistics Agency
ATTN: DLA-WI 22304

Naval Facilities Engr Command
ATTN: Facilities Engr Command
ATTN: Naval Facilities Engr Service Center 93043-4328

US Army HSC
Fort Sam Houston 78234
ATTN: HSLO-F
Fitzsimons Army Medical Ctr
ATTN: HSHG-DPW 80045

Tyndall AFB 32403
ATTN: HQAFCESA Program Ofc
ATTN: Engrg & Srvc Lab

American Public Works Assoc. 64104-1806

US Gov't Printing Office 20401
ATTN: Rec Sec/Deposit Sec (2)

Nat'l Institute of Standards & Tech
ATTN: Library 20899

Defense Tech Info Center 22304
ATTN: DTIC-FAB (2)

93
8/95